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The Impact of Economic Uncertainty Shocks and Liquidity and Credit Risks on the Sovereign Spread Index in Iran, Considering the Shadow Economy Index

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ABSTRACT

The present study aimed to examine the effects of economic uncertainty shocks and liquidity and credit risks on the sovereign spread index in the Iranian economy, while taking into account the shadow economy index. In terms of purpose, this research is applied, and in terms of nature, it is descriptive–analytical and classified as an ex post facto study. The statistical population consisted of Iran's macroeconomic data over the period 1986–2024, extracted from the World Bank database and domestic sources. To construct the composite Economic Policy Uncertainty Index, fluctuations in monetary, fiscal, and exchange-rate variables were extracted using the Hodrick–Prescott filter and subsequently combined through principal component analysis (PCA). In addition, the size of the shadow economy (Shr) was estimated using Tanzi's currency-demand approach. A structural vector autoregression (SVAR) model was employed to analyze the dynamic relationships among the variables and estimate the empirical model. The results of the unit root tests (Phillips–Perron) and cointegration tests (Johansen–Juselius and Engle–Granger) indicated that the variables were stationary at the first-difference level and that long-run equilibrium relationships existed among them. The findings obtained from the SVAR estimation showed that shocks to economic uncertainty, credit risk, liquidity risk, inflation, the debt ratio, and the shadow economy index had positive and statistically significant effects on Iran's sovereign spread index. Furthermore, the impulse response function (IRF) results indicated that the effects of shocks gradually dissipated toward zero in the long run, while the variance decomposition results showed that economic uncertainty and the shadow economy index accounted for the largest shares of fluctuations in the sovereign spread index. Based on these findings, controlling macroeconomic instability, improving fiscal and monetary discipline, and containing the informal sector of the economy are among the most important policy recommendations for reducing sovereign financing cost differentials.

Keywords: Sovereign spread, economic policy uncertainty, liquidity risk, credit risk, shadow economy

Introduction

Sovereign financing conditions constitute one of the most sensitive channels through which macroeconomic instability, financial-sector vulnerability, and policy uncertainty are transmitted to the broader economy. The sovereign spread, broadly understood as the additional financing cost associated with perceived sovereign and macro-financial risk, reflects investors' assessments of a country's repayment capacity, fiscal sustainability, monetary credibility, financial-system resilience, and exposure to domestic and external shocks. In economies



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characterized by persistent inflation, exchange-rate volatility, fiscal imbalances, banking-sector weaknesses, and institutional constraints, fluctuations in sovereign financing costs can become especially pronounced because uncertainty simultaneously influences the expected path of public revenues, debt servicing capacity, asset prices, credit allocation, and liquidity conditions. Recent global experience has reinforced the importance of examining these interdependencies, as economies have faced overlapping monetary, geopolitical, environmental, and financial disturbances that have increased uncertainty regarding inflation, growth, public debt, and policy responses. Panetta emphasizes that the contemporary global economy is increasingly shaped by uncertainty, structural transformation, and changing interactions among monetary, fiscal, financial, and geopolitical forces, making the management of macro-financial vulnerabilities a central policy concern (1). These developments are particularly relevant for economies such as Iran, where long-standing inflationary pressures, exchange-rate instability, banking-sector balance-sheet problems, fiscal dependence on volatile revenue sources, and the substantial presence of informal economic activity may amplify the sensitivity of sovereign financing conditions to economic shocks.

Economic policy uncertainty represents one of the principal mechanisms through which instability can affect sovereign risk. When households, firms, banks, and investors face difficulty in anticipating future monetary, fiscal, regulatory, and exchange-rate policies, they tend to postpone investment, increase precautionary liquidity holdings, demand higher risk premia, and shorten their planning horizons. Policy uncertainty may therefore affect sovereign spreads both directly, through a reassessment of macroeconomic and fiscal risk, and indirectly, through its effects on private-sector investment, banking conditions, financial-market volatility, and economic growth. Monetary policy is particularly important because changes in policy rates, liquidity provision, credit conditions, and unconventional policy instruments can alter yield curves, borrowing costs, asset valuations, and the pricing of risk. Goodhead demonstrates that unconventional monetary policy and forward guidance can influence yield-curve compression and thereby reshape financing conditions and economic incentives (2). Similarly, Hubert et al. show that identical monetary policy actions may generate different macro-financial effects depending on the instruments employed and the economic conditions under which they are implemented, emphasizing the conditional nature of monetary transmission (3). In economies undergoing structural and technological transformation, the monetary transmission mechanism may become even more complex, as traditional policy channels increasingly interact with new forms of financial intermediation, digitalization, systemic shocks, and unconventional instruments (4). Consequently, an assessment of sovereign spreads that ignores policy uncertainty may fail to capture an important source of variation in sovereign financing costs.

The banking sector provides another critical transmission channel linking macroeconomic uncertainty to sovereign risk. Credit risk reflects the possibility that borrowers will fail to meet their contractual obligations, while liquidity risk refers to the possibility that financial institutions will be unable to meet their short-term obligations without incurring excessive losses. These risks are closely connected to macroeconomic conditions because inflation, exchange-rate depreciation, recession, financing constraints, and policy instability can weaken borrower balance sheets and deteriorate banks' asset quality. In the Iranian context, the relationship between monetary policy and credit conditions is especially important because bank-based financing plays a major role in the allocation of financial resources. Evidence from firms listed on the Tehran Stock Exchange suggests that monetary policy and credit risk can materially influence financial investment decisions, demonstrating the importance of the credit channel in Iran's financial system (5). Likewise, Eyni et al. show that inflation and exchange-rate volatility are relevant determinants of nonperforming bank loans in both private and public sectors, indicating that

macroeconomic disturbances can be transmitted directly into banking-sector credit quality (6). When credit risk increases, banks may tighten lending standards, increase lending margins, restrict credit supply, or accumulate nonperforming assets, all of which can undermine economic activity and ultimately intensify fiscal and sovereign vulnerabilities.

Credit risk is also inseparable from the institutional and governance characteristics of the banking and corporate sectors. Weak governance can encourage excessive risk-taking, inefficient allocation of credit, related-party lending, inadequate monitoring, and delayed recognition of impaired assets. Komani's analysis of Iranian private banks emphasizes the relationship between corporate governance, credit risk, and capital adequacy, highlighting the importance of governance mechanisms in maintaining banking-system stability (7). Similarly, Hazrati and Razmjouei identify credit risk as an important factor in the relationship between corporate governance and financial performance, reinforcing the argument that financial outcomes cannot be evaluated independently of the risk structure through which governance arrangements operate (8). Amiri and Rostami Mal Khalifeh further demonstrate that institutional quality and corporate governance are relevant to the efficiency of Iranian banks, suggesting that broader institutional arrangements influence the capacity of financial institutions to transform resources efficiently and manage risk (9). At the firm level, governance, risk, and growth opportunities have also been shown to influence financial policies such as dividend decisions, implying that risk perceptions affect not only bank balance sheets but also corporate financing behavior and capital allocation (10). These findings are relevant to sovereign spreads because banking-system fragility can create contingent fiscal liabilities, increase the probability of government intervention, weaken credit transmission, and raise the expected cost of macroeconomic stabilization.

Liquidity risk constitutes a distinct but closely related dimension of financial vulnerability. A banking system may remain solvent in accounting terms while becoming highly vulnerable if institutions are unable to obtain liquidity rapidly or if market liquidity deteriorates during episodes of stress. Liquidity shortages can generate forced asset sales, valuation losses, funding pressures, and contagion across financial institutions. O'Sullivan et al. demonstrate that liquidity resiliency is dynamic and depends on the capacity of markets and institutions to absorb shocks and recover after liquidity disruptions (11). In a bank-centered financial system, the deterioration of liquidity conditions can rapidly affect both the availability and the cost of credit. If banks become increasingly dependent on central bank financing or short-term deposits while holding relatively illiquid assets, liquidity risk may intensify the transmission of monetary and fiscal shocks. Such pressures can feed into sovereign financing conditions because the government, central bank, and banking system are often financially interconnected. Monetary authorities may be required to supply emergency liquidity, public institutions may recapitalize distressed banks, and fiscal resources may ultimately absorb part of the banking system's losses. Accordingly, liquidity risk may increase sovereign spreads even when the initial shock originates within the financial system rather than from the government budget itself.

The relationship between sovereign risk and financial stability has become even more multidimensional as research increasingly recognizes the importance of systemic and nontraditional sources of uncertainty. Climate-related shocks, natural disasters, and environmental risks illustrate how disturbances originating outside the conventional monetary–fiscal framework can affect production, asset values, credit quality, public expenditures, and sovereign solvency. Ferreira shows that extreme weather events impose substantial economic costs and require adaptation policies that may affect both public and private resource allocation (12). Han et al. demonstrate that disaster damages are unevenly distributed across regions and interact with social vulnerability and public disaster

assistance, illustrating how exogenous shocks may translate into differentiated fiscal pressures (13). At the corporate level, Hao et al. find that exposure to earthquakes can influence firms' green innovation behavior, suggesting that disaster risks alter corporate strategy and investment decisions rather than producing only immediate physical losses (14). Horváth et al. similarly document the effects of hurricanes on stock-market behavior among U.S. energy companies, providing evidence that disaster shocks can generate significant financial-market responses (15). At the household level, previous exposure to natural disasters has also been shown to influence entrepreneurial behavior, revealing that uncertainty can have persistent effects on risk-taking and economic decision-making (16). Although the present study does not directly model climate shocks, this literature is important because it demonstrates a general principle: uncertainty shocks can propagate through multiple sectors and ultimately alter perceptions of financial and sovereign risk.

Recent studies have therefore expanded sovereign-risk analysis beyond conventional fiscal indicators by incorporating broader forms of systemic uncertainty. Naifar provides evidence of spillovers among sovereign credit risks and highlights the role of climate uncertainty in shaping these interactions (17). Liu et al. likewise document a relationship between climate risk and financial stability across countries, showing that systemic risk can emerge from interactions among macroeconomic, environmental, and financial vulnerabilities (18). Mandel et al. further emphasize the global mapping of financial risks under climate change, indicating that shocks can propagate through international financial networks and create heterogeneous risk exposures across countries and sectors (19). These findings strengthen the analytical case for viewing sovereign spreads as the outcome of interconnected risk channels rather than merely as a function of conventional public-debt indicators. They also underscore the importance of assessing the combined effects of uncertainty, banking risk, inflation, leverage, and structural characteristics of the economy within a unified empirical framework.

A related strand of research focuses on the interaction between central banking, credit policy, and structural transformation. Kedward et al. argue that central banks can influence the allocation of credit through policy frameworks, but the effectiveness of such interventions depends on institutional design and the broader policy environment (20). Mertzanis shows that central bank policies are also associated with green bond issuance on a global scale, indicating that monetary and financial policies influence not only aggregate financing conditions but also the composition of financial markets (21). These studies suggest that financial risk cannot be separated from the policy framework within which credit is created and allocated. In an economy facing persistent inflation, exchange-rate pressure, and fiscal constraints, monetary interventions designed to stabilize one part of the financial system may produce consequences elsewhere, including for bank liquidity, credit risk, public borrowing needs, and sovereign spreads. This interdependence is particularly relevant where public-sector financing needs and banking-system balance sheets are closely linked.

The capacity of institutions and firms to respond to risk is also increasingly assessed through sustainability, governance, and investment-efficiency perspectives. Nourmohammadi finds that environmental, social, and governance performance is associated with investment efficiency and that business strategy plays an important role in this relationship (22). Although such firm-level evidence operates at a different analytical level from sovereign-risk modeling, it highlights the broader significance of governance quality and strategic responses in determining how effectively economic agents allocate resources under uncertainty. At the macroeconomic level, poor institutional quality, weak transparency, inefficient capital allocation, and financial repression can magnify the costs

of shocks and reduce confidence in policy credibility. These mechanisms become especially important when a substantial share of economic activity occurs outside the formal, regulated, and taxable sector.

The shadow economy is therefore a particularly important but comparatively underexplored determinant of sovereign financing conditions. The shadow economy encompasses economic activities that are partially or completely concealed from official authorities and are therefore not fully captured by formal taxation, regulation, or statistical reporting. A large shadow economy can affect sovereign risk through several mechanisms. First, it narrows the effective tax base and limits the government's ability to mobilize stable revenues, thereby increasing fiscal dependence on borrowing, monetary financing, or volatile revenue sources. Second, it reduces the accuracy of official macroeconomic statistics and complicates the design and evaluation of monetary and fiscal policies. Third, it can weaken institutional quality by encouraging informality, regulatory avoidance, unrecorded transactions, and cash-based economic activity. Fourth, when economic agents expect instability, inflation, regulatory burdens, or taxation to increase, they may shift additional activity into informal channels, reinforcing the connection between uncertainty and the shadow economy. In Iran, where fiscal, monetary, exchange-rate, and banking-sector conditions have experienced substantial fluctuations over several decades, the shadow economy may therefore serve both as an outcome of uncertainty and as a mechanism that amplifies its effects on sovereign financing costs.

The significance of incorporating the shadow economy becomes clearer when considered alongside the literature on institutional quality, banking efficiency, corporate governance, and systemic risk. A weak formal institutional environment can reduce banking efficiency (9), alter the relationship between governance and credit risk (7), and influence financial policy at the firm level (10). At the same time, economic shocks can increase nonperforming loans (6), weaken liquidity resilience (11), and reshape the transmission of monetary policy (3). When these mechanisms operate in an economy with a substantial informal sector, policy transmission may become less predictable because part of economic activity lies outside conventional regulatory, financial, and tax channels. The resulting uncertainty can increase the risk premium required by lenders and investors, ultimately affecting the sovereign spread.

Despite the extensive literature on monetary policy, credit risk, liquidity conditions, financial stability, governance, and systemic uncertainty, several gaps remain. First, much of the existing literature examines these dimensions separately, whereas sovereign financing conditions arise from their interaction. Second, international research increasingly incorporates new forms of uncertainty, including climate and systemic risks (17-19), but comparatively less attention has been devoted to the interaction between macroeconomic policy uncertainty, banking-sector risks, and the shadow economy in developing and structurally constrained economies. Third, evidence from Iran has primarily concentrated on specific relationships such as monetary policy and corporate investment (5), inflation and nonperforming loans (6), corporate governance and bank efficiency (9), or governance and credit risk (8), without integrating these risk channels into a dynamic sovereign-spread framework. Fourth, because monetary policy effects depend on instruments and economic conditions (2, 3), a static model may be insufficient for capturing the dynamic adjustment of sovereign spreads following structural shocks. An SVAR framework is therefore particularly appropriate because it makes it possible to identify structural shocks, trace their dynamic effects through impulse response functions, and evaluate their relative contributions through variance decomposition.

Accordingly, examining the Iranian economy over a sufficiently long period provides an opportunity to assess how economic policy uncertainty, credit and liquidity risks, inflation, leverage, nonperforming loans, and the shadow economy interact in shaping sovereign financing conditions. Such an analysis can contribute both to the sovereign-

risk literature and to the broader literature on macro-financial stability by linking policy uncertainty to banking-system vulnerabilities and fiscal risk. It is also consistent with recent research emphasizing that contemporary financial instability is increasingly multidimensional, interconnected, and conditional on institutional and policy structures (1, 4). Understanding these relationships is essential for the design of policies aimed at reducing sovereign financing costs, strengthening financial resilience, improving fiscal and monetary discipline, controlling banking-sector vulnerabilities, and limiting the expansion of informal economic activity.

Therefore, the aim of the present study is to investigate the effects of economic policy uncertainty shocks and credit and liquidity risks on the sovereign spread index in Iran, while explicitly accounting for the role of the shadow economy index.

Methods and Materials

The present study is applied in terms of purpose and descriptive–analytical in terms of nature and is categorized as an ex post facto study. Following the studies of David Case et al. (2024), Sadeghi et al. (2023), and Golpe et al. (2023), the objective of the present study is to investigate the effects of economic uncertainty shocks and liquidity and credit risks on the sovereign spread index in Iran, while taking into account the shadow economy index. In addition, Iran's macroeconomic data, including the exchange rate, inflation and monetary policy variables, the underground economy, economic policy uncertainty, and other related indicators, were collected for the period 1986–2024 from the World Bank's World Development Indicators (WDI) database. The research model is specified as follows.

Following David Case et al. (2024), the study examines the shock effects of the sovereign spread arising from inflation and valuation-change risk in the context of unconventional monetary policy in the country.

SP: The sovereign spread index refers to the bank interest-rate spread, defined as the difference between the interest rate received on loans and the interest rate paid on deposits (Sovereign Premium). This rate is calculated as the difference between the average lending rate and the average deposit interest rate.

VIX: Economic policy uncertainty. Given the prevailing economic conditions in Iran and other developing countries, which are frequently characterized by exchange-rate fluctuations, growth in the money supply, inadequate economic growth, and dependence on oil revenues resulting in insufficient attention to tax revenues, it is necessary to construct an indicator specifically suited to these economies that captures policy uncertainty. Accordingly, following Looney et al. (2021), the volatility of three dimensions—fiscal, monetary, and exchange-rate policies—is initially calculated using the Hodrick–Prescott filter. Subsequently, a composite index of fluctuations in these variables is estimated and introduced as an economic uncertainty index. The procedure for measuring uncertainty is such that the fluctuations in monetary policy variables (monetary base and interest rate), fiscal policy variables (budget deficit and taxation), exchange-rate policy (exchange rate), as well as inflation and economic growth, are first calculated using the Hodrick–Prescott filter. Principal component analysis (PCA) is then used to construct the Economic Uncertainty Index. PCA reduces the dimensionality of all observations by constructing a composite index and grouping similar observations. Under this method, correlated variables in a multivariate space are summarized into a set of uncorrelated components, each of which constitutes a linear combination of the original variables. The resulting uncorrelated components are known as principal components (PCs) and are obtained from the eigenvectors of the covariance matrix or correlation matrix of the original variables. Reducing the number of variables and identifying the underlying relationship structure among them constitute two of the most important

applications of PCA. The principal advantage of this technique in econometrics is its ability to eliminate multicollinearity caused by the large number of explanatory variables included in a model.

Table 1. Economic Policy Uncertainty Index

Policy	Abbreviation	Operational Definition
Monetary policy: Monetary policy refers to the set of factors and mechanisms through which the central bank regulates the quantity of money in the economy in order to achieve price stability and sustainable economic growth. The primary monetary policy instruments generally include open-market operations, changes in banks' reserve requirements, and changes in the rediscount rate.	IR	Interest rate: The interest rate refers to the cost of borrowing money that must be paid by the borrower. In other words, it represents the opportunity cost borne by the lender, who could otherwise have generated a return by employing the funds but forgoes that return by lending them.
	M	Monetary base: The monetary base refers to the total amount of highly liquid money created by the central bank. More specifically, it includes all currency in circulation, consisting of banknotes and coins held by the public, together with relevant deposits and the reserves maintained by commercial banks with the central bank.
Fiscal policy: Fiscal policy refers to policies that result in changes in government expenditure or revenue and thereby affect economic output. Fiscal policy was initially emphasized by Keynes, and its principal instruments are government expenditure and tax rates.	BD	Budget deficit: A budget deficit refers to the excess of government expenditures over government revenues. Such a policy is generally employed when the economy is experiencing recessionary conditions.
	TAX	Taxation: Taxation represents the transfer of a portion of society's income or part of the profits generated by economic activities to the government. Tax revenues are generally generated in two ways. The first involves changes in tax rates, whereby governments reduce tax rates during recessions and increase them during economic booms. The second concerns expansion of the tax base, which involves imposing taxes on goods and economic units that were previously exempt from taxation.
Exchange-rate policy: The mechanism through which the exchange rate is determined in an economy is referred to as the exchange-rate regime or exchange-rate policy. Broadly, two dominant exchange-rate systems can be distinguished. Under a fixed exchange-rate system, the central bank intervenes in the market to support an officially determined exchange rate, whereas under a floating exchange-rate system, there is no administratively predetermined exchange rate and the market mechanism determines the exchange rate.	ER	Exchange rate: The exchange rate refers to the unit through which the value of the domestic currency is expressed relative to a foreign currency and exchange transactions are conducted. In other words, it is the amount of domestic currency that must be paid to obtain one unit of another country's currency.
Inflation rate: Inflation refers to the persistent average increase in the general price level. According to this definition, a temporary increase in prices is not regarded as inflation.	INF	In calculating inflation, the price index for 386 commodities in Iran is first calculated, and the average growth rate of the price index is referred to as inflation. Price-index concepts generally distinguish between two major indices: the Producer Price Index and the Consumer Price Index.
Economic growth: Economic growth refers to growth in a country's gross domestic product over a specified period.	GDP	Gross domestic product: GDP is defined as the total monetary value of final goods and services produced by resident economic units of a country during a specified period, whether annually or quarterly. GDP is therefore a flow variable whose value represents the monetary flow of goods and services in an economy over a specific period, generally one year.

CDS: Credit risk, calculated as:

$$CDS = \frac{\text{Outstanding bank loans} + \text{Outstanding bank commitments}}{\text{Total assets}}$$

LR: Liquidity risk, calculated as:

$$LR = \frac{\text{(Government banks' liabilities to the central bank + current, savings, and short-term deposits)} - \text{(cash + coins + net balan}}{\text{Total assets}}$$

Debt Ratio: The debt or borrowing ratio is a financial ratio measuring the degree of leverage of banks in the economy. It is expressed as the ratio of banks' total liabilities to banks' total assets.

CPI: Consumer Price Index (inflation rate).

Shr: Shadow Economy Index. Because information on the size of the underground economy or shadow economy is not readily available, numerous researchers have employed different methods to estimate it, some of which measure tax evasion directly and others indirectly. In the present study, the size of the underground or shadow economy is estimated using Tanzi's currency-demand approach, as described below. The fundamental assumption underlying Tanzi's monetary approach is that all transactions conducted in the informal economy are undertaken in cash to remain concealed. Accordingly, to estimate the size of the informal economy using this approach and on the basis of an autoregressive distributed lag framework, the ratio of currency in circulation to broad money is estimated in the presence of the tax-burden variable according to Equation (1):

$$\left(\frac{C}{M_2}\right)_t = \beta_0 + \beta_1 TaxBar_t + \beta_2 RGDPG_t + \epsilon_t \qquad (1)$$

where (C/M_2)denotes the ratio of currency in circulation to broad money and is treated as the dependent variable. $TaxBar$represents the tax burden and is defined as the ratio of total tax revenues to gross domestic product. $RGDPG$denotes economic growth. After estimating the currency-to-liquidity ratio, $\left(\frac{C}{M_2}\right)_t$, the coefficient of the tax-burden variable is set equal to zero without changing the remaining regression coefficients, and the currency-to-liquidity ratio in the absence of the tax burden, $\left(\frac{C}{M_2}\right)_{WTAX}$, is calculated. In the next stage, illegal money (IM) is obtained by multiplying the difference between these two ratios by the stock of broad money, as shown in Equation (2):

$$IM = \left[\left(\frac{C}{M_2}\right)_{TAX} - \left(\frac{C}{M_2}\right)_{WTAX}\right] \times M_2 \qquad (2)$$

The resulting amount is then subtracted from the broad money supply (M_2) to obtain legal money (LM). Using Equation (3), the velocity of money is subsequently calculated through the quantity-theory relationship:

$$V = \frac{GNP}{LM} \qquad (3)$$

Assuming that the velocity of money is identical in the formal and informal sectors of the economy, the size of the underground economy ($Shadow$) is then estimated by multiplying the stock of money used in the informal economy, or illegal money, by the velocity of money, according to Equation (4):

$$Shadow = IM \times V \qquad (4)$$

ESM: Ratio of nonperforming loans to total loans.

Findings and Results

Principal component analysis is extensively applied across various scientific disciplines. One of its applications in economics is index construction. In the present study, PCA is used to construct the Economic Policy Uncertainty Index. The analysis of many economic phenomena indicates that numerous factors with different dimensions and originating from different domains contribute to the emergence of a particular phenomenon. Incorporating all such factors into econometric analyses not only creates technical problems such as multicollinearity but also increases model complexity and the likelihood of statistical error. Accordingly, the use of techniques such as principal component analysis provides an appropriate means of reducing these problems and obtaining more reliable results. Multivariate data analysis plays a fundamental role in information analysis. Multivariate datasets contain numerous states or variables for each observation. If a dataset contains $n$variables, each variable may represent multiple dimensions. Because multidimensional spaces are often difficult to comprehend intuitively, PCA reduces the dimensionality of observations through a composite index and the classification of similar observations. PCA represents one of the most valuable applications of linear algebra and has been widely used in analytical fields ranging from neural networks to computer graphics because it provides a nonparametric technique for extracting relevant information from complex datasets. Under this method, correlated variables in a multidimensional space are summarized into a set of mutually uncorrelated components, each representing a linear combination of the original variables. These uncorrelated components are referred to as principal components (PCs) and are derived from the eigenvectors of the covariance matrix or correlation matrix of the original variables. In general, the major applications of PCA include reducing the number of variables and identifying the relational structure among variables, which effectively amounts to classifying the variables. Its principal advantage in econometric applications is the elimination of multicollinearity arising from the presence of numerous explanatory variables in the model. Scatter Plot 1 displays observations along the $X_1$and X_2coordinate axes. In the present study, the following variables are employed to construct the composite Economic Policy Uncertainty Index.

IR: Interest rate; M: Monetary base; BD: Budget deficit; TAX: Taxation; ER: Exchange rate; INF: Inflation; GDP: Gross domestic product

To determine the general direction of the observations, an ellipse is drawn to illustrate the correlation among the variables.

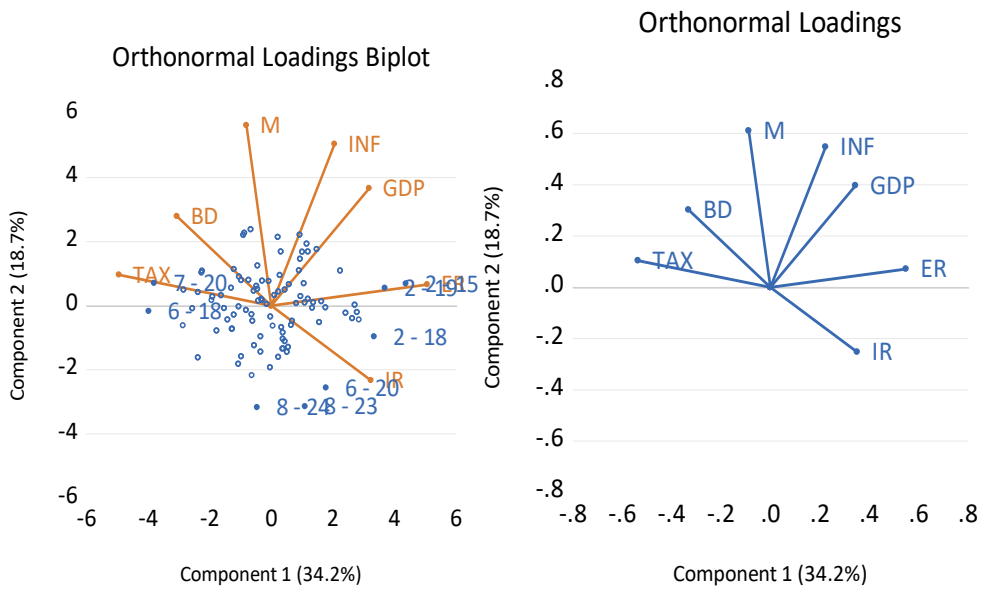


Figure 1. Transformation of Data into Principal Components

The principal direction of the dispersion of observations does not lie strictly along X_1, X_2, or any other individual variable; rather, it lies between them and primarily along the major axis of the ellipse. This axis is referred to as PC_1, representing the first principal component of variability in X_1, X_2, and the other variables. The second component (PC_2) lies along the minor axis of the ellipse and is exactly orthogonal to PC_1, explaining the remaining variation in X_1, X_2, and the other variables. PC_1, PC_2, and the remaining components constitute new axes for explaining X_1, X_2, and the other variables. Therefore, X_1, X_2, and the remaining variables through X_7can be expressed as linear combinations of $PC_1, PC_2, \dots, PC_7$, as follows:

$$X_i = a_{i1}PC_1 + a_{i2}PC_2 + a_{i3}PC_3 + a_{i4}PC_4 + a_{i5}PC_5 + a_{i6}PC_6 + a_{i7}PC_7$$

The values of the principal components can also be calculated using the following equations:

$$PC_1 = W_1X_1 + W_2X_2 + W_3X_3 + W_4X_4 + W_5X_5 + W_6X_6 + W_7X_7$$

$$PC_2 = W_8X_8 + W_9X_9 + W_{10}X_{10} + W_{11}X_{11} + W_{12}X_{12} + W_{13}X_{13} + W_{14}X_{14}$$

...

$$PC_7 = W_{43}X_{43} + W_{44}X_{44} + W_{45}X_{45} + W_{46}X_{46} + W_{47}X_{47} + W_{48}X_{48} + W_{49}X_{49}$$

where $W_i$represents the regression coefficient of the principal components on the variables.

Principal components can be calculated using the original dataset or, when the original data are unavailable, using the covariance matrix or correlation matrix. The correlation matrix is generally used when variables have different measurement units or substantially different variances. When the correlation matrix is employed, standardized variables with a mean of zero and a standard deviation of one are effectively used.

The first extracted principal component accounts for the largest proportion of dispersion in the entire dataset. This means that the first component is correlated with at least some of the variables. The second extracted component has two important characteristics. First, it accounts for the largest share of variance in the dataset that is not explained by the first component. Thus, the second component is correlated with a number of observed variables that do not exhibit a high correlation with the first component. Second, the second component is

uncorrelated with the first component; that is, the correlation between the two components is zero. The remaining components extracted through this method possess the same two properties.

The number of components extracted in each model is equal to the number of variables being examined. Nevertheless, only a specified number of these components may be retained. In many cases, the first two or three components account for a substantial proportion of the dispersion in the data. Therefore, retaining the first two or three components is usually sufficient for subsequent analysis. In some cases, however, additional criteria should be considered when determining the appropriate number of components. These criteria are described below.

The first criterion is the scree test. Plotting the eigenvalues against their corresponding principal components produces a scree plot. This graph illustrates changes in the relative importance of eigenvalues across principal components. Figure 2 presents a hypothetical scree plot. As shown, the eigenvalue of the first vector, representing the variance explained by the first vector, is approximately 2.4, the eigenvalue of the second vector is approximately 1.3, and the eigenvalue of the seventh vector is ultimately below 0.4. Thus, the importance of the eigenvalues initially declines rapidly, after which the rate of decline becomes substantially smaller. The break point identifies the maximum number of principal components that should be retained. A number of PCs smaller than the value indicated by the break point may also be appropriate. Accordingly, based on Figure 2, either the first component or the first three components may be selected.

The second criterion is the eigenvalue criterion. Components with eigenvalues greater than one are retained, whereas the remaining components are disregarded.

The third criterion is the variance criterion. Components explaining a larger percentage of the total dispersion are considered sufficient for subsequent analysis. Generally, the first component accounts for the largest proportion of variance.

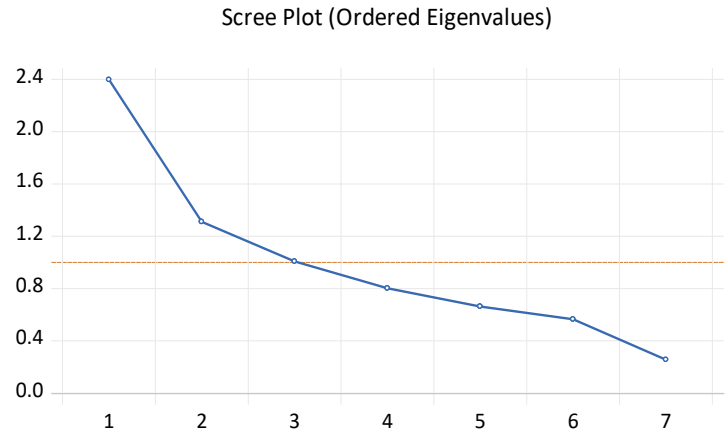


Figure 2. Eigenvalues of the Principal Components

Seven variables—interest rate, monetary base, budget deficit, taxation, exchange rate, inflation, and gross domestic product—were used to construct the Economic Policy Uncertainty Index.

Table 2. Correlation Matrix of Economic Policy Uncertainty Criteria

	IR	M	BD	TAX	ER	INF	GDP
IR	1.000000						
M	-0.066561	1.000000					
BD	-0.157517	0.199898	1.000000				
TAX	-0.344988	0.205616	0.312675	1.000000			
ER	0.432166	0.060198	-0.282109	-0.663387	1.000000		
INF	0.011065	0.121488	-0.009326	-0.225045	0.176880	1.000000	

GDP	0.021601	0.051334	-0.189983	-0.263352	0.383599	0.283143	1.000000

Table 2 shows that relatively high correlations exist among the aforementioned criteria. Accordingly, PCA is used to reduce the dimensionality of the variables and extract the Economic Policy Uncertainty Index.

Table 3 indicates that the eigenvalue of the first component is larger than those of the remaining components and that approximately 25% of the dispersion in the dataset is represented by this component. Therefore, this component is selected as the most appropriate component for constructing the index.

Table 3. Results of Estimating the Composite Economic Policy Uncertainty Index Using PCA

Principal Components Analysis

Eigenvalues: Sum = 7, Average = 1

Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	2.396286	1.085454	0.3423	2.396286	0.3423
2	1.310833	0.303116	0.1873	3.707119	0.5296
3	1.007717	0.206004	0.1440	4.714836	0.6735
4	0.801713	0.139636	0.1145	5.516549	0.7881
5	0.662077	0.096797	0.0946	6.178625	0.8827
6	0.565279	0.309184	0.0808	6.743905	0.9634
7	0.256095	—	0.0366	7.000000	1.0000

Eigenvectors (Loadings)

Variable	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7
IR	0.351392	-0.253062	0.605601	0.131235	-0.123174	0.625273	-0.149568
M	-0.087394	0.610223	0.477813	-0.479860	-0.262111	-0.176898	-0.247838
BD	-0.331760	0.301830	0.389201	0.506716	0.622904	-0.050419	0.006613
TAX	-0.536287	0.104042	-0.009941	-0.223811	-0.111877	0.522700	0.604689
ER	0.549868	0.071204	0.243049	-0.128570	0.180626	-0.283190	0.710035
INF	0.223425	0.547003	-0.220610	0.586852	-0.477044	0.121988	0.123909
GDP	0.344883	0.396711	-0.381608	-0.291090	0.505374	0.454870	-0.176093

The relationship between the observed variables and the principal components can be expressed through factor loadings, while estimates of the principal components can be obtained using factor scores, as follows:

$$PC_1 = 0.35IR - 0.08M - 0.33BD - 0.53TAX + 0.54ER + 0.22INF + 0.34GDP$$

Accordingly, the above equation represents the linear combination of the first principal component (PC_1) used to construct the Economic Policy Uncertainty Index.

Finally, the weight of each sub-index in the composite Economic Policy Uncertainty Index is presented in the following table.

Table 4. Relative Importance of Variables in the Composite Economic Policy Uncertainty Index

Variable	Relative Importance
Interest rate	0.3423
Monetary base	0.1873
Budget deficit	0.1439
Taxation	0.1146
Exchange rate	0.0946
Inflation	0.0807
Gross domestic product	0.0366
Total	100

Table 4 presents the relative importance of the components of the overall Economic Policy Uncertainty Index according to the selected variables under the rotated-component regression method. Based on the estimated

weights, the interest rate has the largest contribution to the composite Economic Policy Uncertainty Index. Finally, the composite Economic Policy Uncertainty Index is extracted using the principal component analysis procedure and is subsequently incorporated into the final research model.

The stationarity of the research variables is examined next. If time series move together in a coordinated manner, such comovement may indicate the existence of a potential long-run equilibrium relationship. In other words, when two time-series variables exhibit coordinated movements, it may be possible to specify a long-run equilibrium relationship between them; such variables are said to be cointegrated. In simple terms, cointegration occurs when two time series approximately move along the same long-run trajectory. Economic analysis generally assumes the existence of long-run equilibrium relationships among variables included in an economic theory. Applied econometric analyses traditionally estimate long-run relationships under the assumption that the means and variances of the variables remain constant over time and are independent of the time factor, thereby implicitly assuming behavioral stability. Nevertheless, applied studies have shown that behavioral stability does not hold for many economic time series. Consequently, conventional F- and t-tests obtained from estimation procedures in which the stationarity condition is violated are invalid and may yield misleading results. This problem is known as spurious regression. To ensure the reliability of empirical findings, researchers have therefore revised conventional estimation procedures and systematically examine the stationarity and cointegration properties of variables.

Cointegration analysis has been regarded as one of the most revolutionary developments in econometrics since the mid-1980s. In simple terms, cointegration analysis examines the comovement of variables even when the variables themselves may be nonstationary and display upward or downward trends over time. Their joint movement may nevertheless produce a stable linear relationship in the long run, thereby generating an equilibrium relationship among them. Conversely, when no long-run linear relationship exists, the variables are regarded as noncointegrated. More generally, cointegration analysis provides a method for estimating long-run equilibrium parameters in relationships involving nonstationary variables. It therefore constitutes an important framework for specifying, estimating, and testing dynamic models and can consequently be used to assess the empirical validity of economic theories. Cointegration analysis can also be used to estimate short-run disequilibrium parameters because such parameters can be derived in conjunction with the long-run parameters obtained from cointegration analysis. Models constructed for this purpose are known as error-correction models. Error-correction models link short-run fluctuations in variables to their long-run equilibrium values. By definition, a time series is said to be strictly or strongly stationary when its joint probability density function, for every fixed value of k, does not depend on t. Under such conditions, its distribution and consequently its moments, including the mean and variance, are time invariant. In practice, however, examining strict stationarity is complex, and strong stationarity is generally unnecessary for time-series analysis. Instead, weak stationarity is more commonly investigated. A time series is said to be weakly stationary when the relevant stationarity conditions are satisfied.

Table 5. Results of the Phillips–Perron Unit Root Test for the Model Variables

Variable	PP Statistic	Probability	Integration Status
CDS	0.706538	0.8635	—
D(CDS)	-10.89521	0.0000	I(1)
CPI	-0.743894	0.3871	—
D(CPI)	-9.166059	0.0000	I(1)
DEBT	0.665645	0.9531	—
D(DEBT)	-12.51469	0.0000	I(1)
ESM	-2.623637	0.2728	—

D(ESM)	-5.916729	0.0001	I(1)
LR	-2.980257	0.1515	—
D(LR)	-7.838104	0.0000	I(1)
SHR	1.757753	0.9953	—
D(SHR)	-11.46529	0.0000	I(1)
TRSP	-0.800990	0.3620	—
D(TRSP)	-9.512460	0.0000	I(1)
VIX	-1.457232	0.1332	—
D(VIX)	-11.19993	0.0000	I(1)

Based on the unit root test results for the model variables, all variables become stationary after first differencing and are therefore integrated of order one, $I(1)$.

Two major techniques are commonly employed to examine cointegration: the Engle–Granger method and the Johansen method. The Engle–Granger procedure examines the existence of only one long-run relationship between two or more variables. When the number of variables exceeds two, this procedure encounters limitations in identifying long-run relationships because only a single error component is incorporated into the equation (Nofarasti, 2008). Furthermore, part of the information contained in the data may be lost through differencing. The Johansen procedure provides several advantages over other cointegration tests. One important advantage is that it avoids relying solely on differencing to obtain stationary variables, because differencing may eliminate information related to the long-run equilibrium properties among the variables. By estimating an error-correction component and incorporating it into equations formulated in differences, the Johansen procedure preserves the long-run equilibrium characteristics of the system. The method identifies and estimates cointegrating vectors, that is, the coefficients associated with long-run equilibrium relationships among the variables. The relationship between the underlying system and cointegration makes it possible to derive the cointegrating vectors directly from the coefficients of the vector autoregressive model (Nofarasti, 1999). In the Johansen–Juselius cointegration procedure used in the present study to examine long-run relationships among the model variables, the first step involves determining the cointegration rank of the variables, which is of particular importance (Johansen & Juselius, 1991). In the second stage, after establishing the cointegration rank, it is determined whether the model variables are cointegrated.

Following the Johansen methodology, the trace test (λ_{Trace}) and maximum eigenvalue test ($\lambda_{\max}$) are employed to determine the number of cointegrating vectors. As shown in the table, under the trace test, the null hypothesis that no cointegrating vector exists is rejected, while the alternative hypothesis indicating the existence of more than one cointegrating vector is accepted. The distinction between the maximum eigenvalue and trace statistics is that the alternative hypothesis associated with the $\lambda_{\max}$statistic is more specifically defined. The results of the $\lambda_{\max}$and λ_{Trace}tests may occasionally differ. The $\lambda_{\max}$test effectively has a more explicit alternative hypothesis. In the event of conflicting results, selecting the smaller number of cointegrating vectors is generally preferable (Enders, 2007). The results are presented below.

Table 6. Johansen Trace and Maximum Eigenvalue Cointegration Tests

Unrestricted Cointegration Rank Test (Trace)

Hypothesized Number	Eigenvalue	Trace Statistic	0.05 Critical Value	Probability
None *	0.832893	206.6339	159.5297	0.0000
At most 1 *	0.761192	144.0147	125.6154	0.0023
At most 2	0.660660	93.89145	95.75366	0.0667
At most 3	0.474198	56.06512	69.81889	0.3754

At most 4	0.383901	33.56602	47.85613	0.5257
At most 5	0.217278	16.61384	29.79707	0.6684
At most 6	0.159240	8.039623	15.49471	0.4612
At most 7	0.054701	1.968902	3.841466	0.1606

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized Number	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Probability
None *	0.832893	62.61914	52.36261	0.0033
At most 1 *	0.761192	50.12327	46.23142	0.0183
At most 2	0.660660	37.82633	40.07757	0.0878
At most 3	0.474198	22.49910	33.87687	0.5690
At most 4	0.383901	16.95219	27.58434	0.5841
At most 5	0.217278	8.574212	21.13162	0.8652
At most 6	0.159240	6.070721	14.26460	0.6042
At most 7	0.054701	1.968902	3.841466	0.1606

Under both tests, the hypothesis that at least two cointegrating vectors exist is supported.

Engle and Granger (1987) argued that if the Dickey–Fuller test is applied to the residuals of an estimated model and the residual series is found to be stationary, this provides evidence of cointegration. Nevertheless, caution is necessary when applying this procedure because conventional critical values are not fully appropriate; instead, the critical values developed specifically by Engle and Granger should be employed. In this framework, stationarity and nonstationarity are examined by applying a unit root test to the residuals, and the hypotheses are specified as follows:

H_0:No cointegration

H_1:Cointegration

The test results are reported in the following table.

Table 7. Cointegration Test

Engle–Granger Test

Test Statistic	Probability
-5.730189	0.0000

The optimal lag length for the models under investigation is first determined.

After establishing the stationarity properties of the model variables, the first issue in vector autoregressive models is selecting the optimal lag length. In the present study, the Schwarz–Bayesian Criterion (SC), Akaike Information Criterion (AIC), Final Prediction Error (FPE), Hannan–Quinn Criterion (HQ), and likelihood-ratio (LR) criterion are used to determine the appropriate lag length.

Table 8. Determination of the Optimal Lag Length for the Sovereign Spread Model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	251.8502	NA	1.81e-16	-13.54724	-13.19534	-13.42442
1	369.8029	176.9289*	2.83e-18*	-16.54460*	-13.37756*	-15.43922*
2	433.5348	67.27257	1.76e-17	-16.52971	-10.54753	-14.44177
3	563.2902	79.29498	3.17e-18	-15.18279	-11.38546	-14.11229

* Indicates the optimal lag.

LR: Likelihood-ratio criterion; **FPE:** Final Prediction Error criterion; **AIC:** Akaike Information Criterion; **SC:** Schwarz–Bayesian Criterion; **HQ:** Hannan–Quinn Criterion

The results presented in the table indicate that the likelihood-ratio, Final Prediction Error, Akaike, and Hannan–Quinn criteria identify lag one as the optimal lag length for the model. Because the Schwarz–Bayesian criterion follows the principle of parsimony and places greater emphasis on reducing the number of parameters and simplifying the system rather than maximizing goodness of fit, it is particularly appropriate for relatively small samples, including the sample employed in the present study. Accordingly, one lag is selected as the optimal lag length.

To ensure that the estimated regression is not spurious, the unit-root properties of the overall regression model were also examined. If the SVAR model is unstable, the resulting estimates cannot be regarded as reliable. The stability of the estimated model is therefore evaluated using the AR roots graph. This graph presents the inverse roots of the characteristic polynomial of the AR process. If the absolute values of all inverse roots are smaller than one and lie within the unit circle, the estimated SVAR model is stable. The AR roots graph presented in Figure 3 indicates that the inverse of every characteristic root lies within the unit circle; therefore, the estimated SVAR model satisfies the required stability condition.

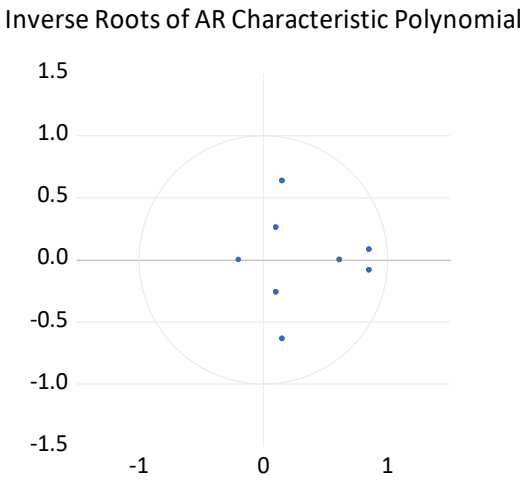


Figure 3. Unit Root Stability Test for the Sovereign Spread Model

The SVAR estimation results examining the response of the sovereign spread index to the explanatory variables are reported in the following table. The table represents the system of equations relating structural shocks to reduced-form shocks.

Table 9. Estimated Long-Run Equilibrium Relationship for the Research Model

Variables	Coefficient	Standard Error	Test Statistic	Probability
Economic policy uncertainty shock	0.074571	0.028124	2.651460	0.0122
Credit risk shock	0.419257	0.121535	3.449690	0.0022
Liquidity risk shock	0.530375	0.114026	4.651335	0.0001
Debt-ratio shock	0.236612	0.084965	2.784825	0.0055
Inflation shock	0.252209	0.084143	2.997371	0.0028
Shadow Economy Index shock	0.366688	0.113132	3.241241	0.0012
Nonperforming-loan ratio shock	0.207265	0.071960	2.880267	0.0041

The t-statistic is used to examine the statistical significance of the coefficients of the independent variables in the model.

To determine whether the null hypothesis should be accepted or rejected, the calculated t-statistic is compared with the critical t-value at $N - K$degrees of freedom and a 95% confidence level. If the absolute value of the

calculated t-statistic exceeds the corresponding critical value, the test statistic falls within the rejection region and the null hypothesis is rejected. Under these circumstances, the relevant coefficient is statistically significant at the 95% confidence level, indicating the existence of a statistically significant relationship between the independent and dependent variables.

The SVAR estimation results indicate that the coefficients of the principal variables and the shocks operating through the system of matrix equations are statistically significant and consistent with the structural conditions of the Iranian economy. Among the principal results requiring interpretation, shocks originating from economic uncertainty exert a positive and statistically significant effect on the sovereign spread index. Likewise, credit-risk and liquidity-risk shocks have positive effects on the sovereign spread.

To provide a more comprehensive interpretation of the estimated long-run equilibrium relationships in the structural vector autoregressive (SVAR) model, the impulse response functions and variance decomposition should be examined. In other words, the SVAR framework provides two powerful instruments for analyzing economic fluctuations: impulse response functions (IRFs) and variance decomposition. Therefore, following estimation of the SVAR model, the IRF and variance-decomposition results can be analyzed. An impulse response function describes the effect of a one-standard-deviation shock to an endogenous variable within the model. For the model employed in the present study, the response of the sovereign spread index to a shock or sudden one-standard-deviation change in each endogenous variable is illustrated graphically in Figure 4. The horizontal axis represents time in annual periods, while the vertical axis represents the percentage change in the variable.

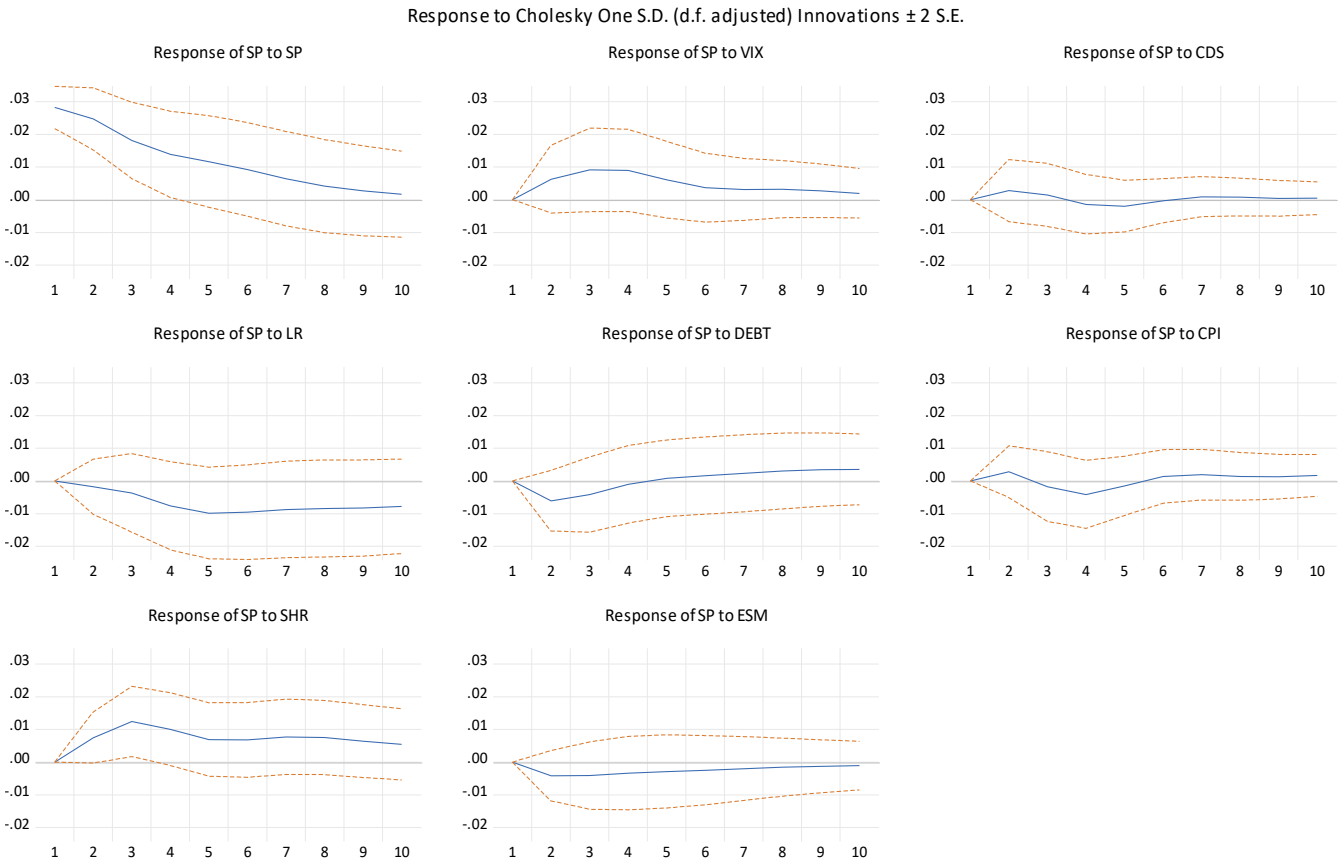


Figure 4. Impulse Response Function Results for the Model

The impulse response function results show that the response of the sovereign spread index to shocks originating from the endogenous variables of the model gradually converges toward zero in the long run.

Discussion and Conclusion

The findings of the present study indicate that economic policy uncertainty, credit risk, liquidity risk, the debt ratio, inflation, the shadow economy, and the ratio of nonperforming loans exert positive and statistically significant effects on the sovereign spread index in Iran. The SVAR estimates showed that liquidity risk had the largest estimated coefficient among the explanatory shocks, followed by credit risk, the shadow economy index, inflation, the debt ratio, the nonperforming-loan ratio, and economic policy uncertainty. These findings suggest that sovereign financing conditions in Iran are not determined solely by fiscal variables but are also strongly influenced by banking-sector fragility, macroeconomic instability, and structural characteristics of the economy. The impulse response functions further indicated that the effects of shocks gradually dissipate toward zero over the long run, implying that the system eventually returns toward its equilibrium path after disturbances. At the same time, the variance decomposition results showed that economic policy uncertainty and the shadow economy account for a considerable proportion of fluctuations in the sovereign spread. Taken together, these results support a macro-financial interpretation of sovereign risk in which fiscal sustainability, financial intermediation, monetary instability, and informality interact dynamically rather than operating as isolated determinants.

The positive effect of economic policy uncertainty on the sovereign spread is consistent with the general theoretical expectation that heightened uncertainty increases the risk premium demanded by investors and lenders. When future monetary, fiscal, exchange-rate, and regulatory policies become less predictable, economic agents face greater difficulty in estimating future returns, repayment capacity, and policy credibility. As a result, they tend to demand additional compensation for bearing uncertainty. This interpretation is consistent with Panetta, who emphasizes that the contemporary global economy is characterized by heightened uncertainty and structural change, conditions that complicate policy implementation and increase the importance of credible macroeconomic management (1). The finding also corresponds with Hubert et al., who show that the effects of monetary policy instruments depend strongly on prevailing economic conditions and policy configurations, indicating that uncertainty surrounding policy transmission itself can alter macro-financial outcomes (3). Similarly, Goodhead demonstrates that unconventional monetary policy and forward guidance can materially affect the yield curve and financing conditions (2). In the Iranian context, where monetary expansion, fiscal imbalance, exchange-rate pressures, and inflation frequently interact, uncertainty surrounding the direction and effectiveness of economic policies can therefore translate directly into higher sovereign financing costs.

The estimated positive relationship between credit risk and the sovereign spread further confirms the importance of the banking–sovereign nexus. Higher credit risk implies a greater probability of borrower default, deterioration in bank asset quality, rising loan-loss provisions, and declining bank profitability. These conditions can increase the probability that the banking system will require liquidity assistance, recapitalization, regulatory forbearance, or other forms of public intervention, thereby generating potential contingent liabilities for the government. The present result is consistent with Alinejad et al., who found that monetary policy and credit risk affect financial investment among companies listed on the Tehran Stock Exchange, indicating that credit conditions have important consequences for resource allocation and financing behavior in Iran (5). It is also aligned with Hazrati and Razmjouei, who emphasize the role of credit risk in the relationship between corporate governance and financial performance (8). Komani similarly reports that corporate governance is related to credit risk and capital adequacy in Iranian private banks, reinforcing the importance of credit-risk management for banking stability (7). Therefore, the positive credit-risk

coefficient observed in the present study can be interpreted as evidence that deterioration in banking-sector credit quality ultimately contributes to higher perceived sovereign risk.

The results also showed that liquidity risk had a positive and statistically significant effect on the sovereign spread and, among the estimated coefficients, represented the strongest direct effect. This finding is economically plausible because liquidity shortages can rapidly destabilize banking institutions even when their underlying assets have not yet fully deteriorated. An increase in liquidity risk may force banks to rely more heavily on central bank financing, liquidate assets under unfavorable conditions, raise deposit rates, or restrict lending. Such responses can transmit financial stress to the broader economy and, through the sovereign–bank relationship, increase the perceived fiscal burden associated with financial instability. The finding is supported by O'Sullivan et al., who emphasize the importance of liquidity resiliency and the capacity of financial markets and institutions to absorb and recover from liquidity shocks (11). In the context of Iran, where banking institutions are closely connected with monetary authorities and public-sector financing conditions, liquidity shortages can increase both monetary pressures and implicit government liabilities. Hence, a rise in liquidity risk can widen the sovereign spread by increasing expectations of future intervention costs and by weakening confidence in the stability of the financial system.

The positive and significant effect of the debt ratio on the sovereign spread is also consistent with the expected relationship between leverage and risk. A higher debt ratio indicates that a larger share of bank assets is financed by liabilities, which can increase vulnerability to funding shocks and reduce the capacity of financial institutions to absorb losses. Although the debt ratio in the present study is measured at the banking level, the resulting risk can spill over into sovereign financing conditions because leveraged banks are more sensitive to interest-rate changes, asset deterioration, and deposit withdrawals. The relationship between banking efficiency, institutional quality, and governance reported by Amiri and Rostami Mal Khalifeh supports this interpretation, as inefficient or weakly governed banks may accumulate liabilities without generating sufficiently productive assets (9). Ghanbari Dahlan and Mahmoudi also show that risk and firm-specific characteristics influence financial policies, confirming the broader proposition that leverage and risk conditions shape financing decisions and financial resilience (10). Accordingly, higher banking leverage can intensify the transmission of financial-sector vulnerabilities to sovereign risk.

The significant positive relationship between inflation and the sovereign spread provides additional evidence that macroeconomic instability increases sovereign financing costs. High inflation erodes the real value of financial assets, weakens predictability, increases interest-rate uncertainty, and can reduce confidence in monetary policy. It may also increase nominal government expenditures and borrowing requirements while simultaneously weakening the real value and stability of tax revenues. In the banking sector, inflation can deteriorate borrower repayment capacity and affect the real burden and profitability of loans. The results are consistent with Eyni et al., who found that inflation and exchange-rate volatility affect nonperforming loans in both private and public banking sectors in Iran (6). The finding is also aligned with Mahmoudifard and Hosseini Aliabad, who discuss the increasing complexity of monetary policy under systemic shocks and structural transformation, emphasizing that inflation management has become intertwined with broader financial and institutional challenges (4). Therefore, the positive inflation coefficient in the sovereign-spread equation can be interpreted as reflecting both direct macroeconomic risk and indirect banking-sector deterioration.

One of the most important findings of the study is the positive and statistically significant effect of the shadow economy index on the sovereign spread. This result suggests that a larger informal economy increases sovereign

financing risk by weakening the government's revenue base, reducing tax compliance, limiting the reliability of official statistics, and undermining the effectiveness of formal monetary and fiscal policy channels. As informal economic activity expands, a greater proportion of income and transactions escapes taxation and regulation. This can increase fiscal deficits, reduce the predictability of government revenue, and make public debt management more difficult. The finding also has an institutional dimension. Nourmohammadi emphasizes the importance of environmental, social, and governance performance for investment efficiency, highlighting the role of institutional quality and governance structures in determining the effectiveness of resource allocation (22). Amiri and Rostami Mal Khalifeh similarly demonstrate that institutional quality affects banking efficiency (9). From this perspective, a large shadow economy can be regarded not only as a fiscal problem but also as a manifestation of institutional weaknesses that may increase uncertainty, reduce policy effectiveness, and ultimately widen sovereign spreads.

The importance of the shadow economy is further reinforced by the variance decomposition results, which showed that economic uncertainty and the shadow economy accounted for substantial shares of sovereign-spread fluctuations. This finding suggests that structural and institutional factors may have persistent explanatory power beyond conventional macroeconomic variables. The result is conceptually consistent with recent studies emphasizing that sovereign and financial risk can be amplified by broad sources of uncertainty that are not captured by traditional fiscal indicators. Naifar shows that sovereign credit risk is subject to spillovers and is influenced by uncertainty associated with climate-related conditions (17). Liu et al. similarly provide cross-country evidence that climate risk can affect financial stability (18), while Mandel et al. map the transmission of global financial risks under climate change and demonstrate that financial vulnerabilities can propagate across countries and sectors (19). Although these studies focus on climate-related uncertainty rather than informality, their findings support the broader interpretation that sovereign risk reflects multidimensional and interconnected sources of uncertainty. In the Iranian economy, the shadow economy may play an analogous structural role by weakening fiscal capacity and increasing uncertainty regarding the true size, taxable capacity, and formal structure of economic activity.

The positive effect of the nonperforming-loan ratio on the sovereign spread also supports the view that weaknesses in bank balance sheets can become sovereign-risk factors. An increase in nonperforming loans reduces bank profitability, ties up capital, weakens lending capacity, and raises the probability that banks will require regulatory or public-sector support. This finding directly aligns with Eyni et al., who show that inflation and exchange-rate volatility contribute to nonperforming loans in the Iranian banking system (6). It is also compatible with the findings of Komani regarding the relationship among governance, credit risk, and capital adequacy in Iranian private banks (7). When nonperforming loans increase alongside liquidity shortages and high leverage, vulnerabilities may reinforce one another, intensifying the sovereign–bank feedback loop. Therefore, the positive coefficient for the nonperforming-loan ratio provides further evidence that sovereign spread dynamics in Iran are closely connected with the health of the banking system.

The results of the impulse response analysis showed that the response of the sovereign spread to shocks gradually converges toward zero over the long run. This pattern suggests that although shocks generated by uncertainty, financial risk, inflation, leverage, and informality initially affect sovereign financing conditions, their influence is not permanently explosive within the estimated system. Instead, the economy exhibits a tendency toward adjustment and restoration of equilibrium over time. This finding is compatible with the broader literature on policy transmission, which indicates that financial and monetary shocks often generate dynamic responses that vary over time rather than remaining constant. Goodhead's analysis of yield-curve compression under forward

guidance and unconventional monetary policy illustrates that the effects of policy interventions unfold through time-dependent financial-market channels (2). Hubert et al. likewise show that the effects of monetary actions are conditional and may differ according to the state of the economy (3). The observed convergence of the impulse responses therefore supports the use of a dynamic SVAR framework, as the impact of a shock cannot be adequately captured through contemporaneous coefficients alone.

The broader implications of the findings are also consistent with recent literature on systemic risk. Environmental and natural-disaster studies show that external shocks can affect corporate behavior, financial markets, and public-sector obligations. Ferreira highlights the economic costs associated with extreme weather events and adaptation policies (12), while Han et al. demonstrate that disaster damages and social vulnerability influence the distribution of public assistance (13). Hao et al. show that natural disasters can alter corporate green innovation behavior (14), and Horváth et al. identify stock-market effects of hurricanes among U.S. energy firms (15). Yao et al. further demonstrate that disaster experiences can alter household entrepreneurial behavior (16). These studies collectively reinforce the idea that shocks originating in one part of the economy can alter financial behavior and risk perceptions elsewhere. The present findings extend this logic to the sovereign-spread context by showing that macroeconomic uncertainty, banking-sector risks, and structural informality can jointly influence sovereign financing conditions.

The findings also underline the importance of recognizing that monetary and credit policies do not operate independently of structural and institutional conditions. Kedward et al. emphasize that the effectiveness of credit policy depends on the institutional framework within which central banks operate (20), while Mertzanis shows that central bank policies can influence the development and composition of financial markets, including green bond issuance (21). These studies support the present finding that policy uncertainty, banking risks, and sovereign financing conditions must be analyzed within an integrated system. In Iran, policies aimed solely at controlling one macroeconomic indicator may be insufficient if banking-sector vulnerabilities and the shadow economy remain unaddressed. The interaction among fiscal conditions, monetary credibility, banking stability, and formalization of economic activity is therefore central to reducing sovereign risk.

The present study is subject to several limitations. First, the analysis relies on annual macroeconomic data for 1986–2024, which restricts the number of available observations and may reduce the ability of the model to capture short-term fluctuations occurring within each year. Second, some of the variables, particularly the shadow economy index and economic policy uncertainty index, are not directly observable and therefore had to be estimated through indirect procedures. The shadow economy was measured using the Tanzi currency-demand approach, while economic policy uncertainty was constructed from selected monetary, fiscal, exchange-rate, inflation, and output variables through the Hodrick–Prescott filter and principal component analysis. Accordingly, the resulting indicators are sensitive to methodological choices and variable selection. Third, the sovereign spread was operationalized using the difference between lending and deposit rates because internationally comparable market-based sovereign spread data are not consistently available for Iran across the full study period. Fourth, the SVAR specification identifies dynamic relationships within the selected system but cannot incorporate every institutional, political, external, geopolitical, or sanctions-related factor that may influence sovereign financing conditions. Finally, structural breaks associated with major economic reforms, sanctions episodes, exchange-rate regime changes, banking reforms, and exceptional macroeconomic shocks may have altered the underlying relationships over time.

Future studies could extend the present analysis by using quarterly or monthly data wherever reliable observations are available, thereby providing a more detailed assessment of the timing and persistence of shocks.

Alternative measures of sovereign risk, including market-based risk premia, sovereign credit ratings, or synthetic sovereign-risk indices, could also be examined and compared with the banking spread measure employed in this study. Future research may estimate the shadow economy through alternative approaches such as the MIMIC model and compare the resulting estimates with those obtained through the Tanzi method. Researchers could also construct alternative uncertainty indices using textual analysis, news-based indicators, exchange-rate volatility, fiscal forecasting errors, or high-frequency financial variables. Time-varying parameter VAR, Markov-switching VAR, nonlinear ARDL, threshold models, and Bayesian VAR techniques could be used to investigate whether the effects of uncertainty and financial risks differ across expansionary, recessionary, high-inflation, or crisis regimes. Further studies could explicitly model the role of sanctions, oil-price shocks, exchange-rate regimes, fiscal dominance, central bank financing of banks, and political or geopolitical disturbances. Comparative studies involving Iran and other emerging or resource-dependent economies would also help determine whether the observed relationships are specific to Iran or reflect more general characteristics of economies with large informal sectors and bank-centered financial systems.

From a practical perspective, the findings suggest that reducing sovereign financing costs requires coordinated macroeconomic, fiscal, monetary, banking, and institutional policies rather than isolated interventions. Monetary authorities should strengthen liquidity-risk monitoring, improve early-warning systems for banking distress, and reduce excessive dependence of banks on central bank resources. Supervisory institutions should enforce stricter credit-risk assessment standards, improve the classification and resolution of nonperforming loans, strengthen capital adequacy, and require greater transparency regarding bank balance sheets. Fiscal authorities should pursue predictable and credible fiscal frameworks, reduce persistent budget imbalances, broaden sustainable tax revenues, and limit policy measures that create uncertainty for households, firms, and financial institutions. Measures designed to reduce the size of the shadow economy should focus on simplifying tax compliance, expanding digital and traceable transactions, improving regulatory quality, strengthening institutional trust, and reducing incentives for informal activity. Greater coordination between fiscal and monetary authorities is also required to avoid policy inconsistencies that amplify inflationary expectations or liquidity pressures. Finally, maintaining greater stability in inflation, exchange-rate conditions, and economic policymaking can contribute to reducing uncertainty, improving financial-sector resilience, and narrowing the sovereign financing spread over time.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adheried in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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