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Original Research Article

Global Economic Policy Uncertainty and Non-Performing Loans in Iranian Banks: Dynamic Correlation using the DCC-GARCH Approach

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The aim of this article is to investigate the dynamic correlation between the Global Economic Policy Uncertainty index (GEPU) and Non-Performing Loans (NPL) in Iran. The relationship between economic uncertainty and banking performance indices is significant because of the systemic importance of banks in every economy. We evaluated this relationship in this developing country, especially under economic sanctions. In this study, we used the Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) to assess the relationship between Global Economic Policy Uncertainty and Non-Performing Loans of Iranian banks using the statistics of these two indicators by R and Eviews programming and statistical software in the period from 2004 to 2021. Our results show that Iranian banks' Non-Performing Loans (NPL) are rather associated with Global Economic Policy Uncertainty (GEPU) during major global shocks such as the global financial crisis in 2008 or the Covid-19 pandemic. However, despite fluctuations in the correlation between Non-Performing Loans and Global Economic Policy Uncertainty over time, this study also illustrates that these correlations in some periods are generally somewhat low that some of the reasons could be the sanctions imposed on Iran's economy and banking system, imposed loans to banks by the government, forced interest rate, etc., which led to a limited connection among Iranian banks and global banking system. To prove this claim we estimate the model for some countries with an open economy, like Japan, Singapore, the US, Turkey, and Spain. The result shows that this correlation is much higher in comparison to Iran.

Keywords: Global Economic Policy Uncertainty (GEPU), Non-Performing Loans (NPL), DCC-GARCH, Banks.
JEL Classification*:* G21, C32

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1 Introduction

After the global financial crisis in 2008, the uncertainty of economic policies has been increasing because the economic policies implemented in each country often change and therefore intensify the fluctuations of some variables. In recent years, economic policy uncertainty has become an important and influential variable on the financial market and various assets (Zhou and Yan, 2015). Economic uncertainty is unpredictable changes in economic variables that can significantly impact other economic variables and institutions such as banks and credit institutions, especially in developing countries, such as Iran (Rezaei and Norouzi, 2019). The high Global Economic Policy Uncertainty (GEPU) confuses international investors and increases domestic investors' uncertainty about the future. It affects the economic policies pursued by economic decision-makers (Lee et al., 2019). Understanding how Global Economic Policy Uncertainty (GEPU) affects macroeconomic variables and different markets in investment policy and decisions is important (Fang et al., 2018).

Different markets for goods and financial assets fluctuate in different global economic conditions; with the increasing influence of different countries globally and the transfer of information between different markets of each country, any fluctuation in Global Economic Policy affects different markets (Ashna and Lal, 2020).

When unfavorable economic conditions and economic uncertainty in the world occur with various phenomena, many economic factors, including the level of bank lending, are affected. For example, in the euro area, Non-Performing Loans (NPL) ratio (Non-Performing Loans to Total Gross Loans) fell 3.4 percent in the third quarter of 2019, while in recent years, it has seen an uptrend due to the Covid-19 outbreak crisis (Louri and Karadima, 2020).

Various macroeconomics factors affect Non-Performing Loans (NPLs) in the banking system of different countries of the world; Factors such as GDP[1] growth, unemployment, inflation, and even poor performance of bank managers. Moreover, we know that Economic Policy Uncertainty (EPU) and Global Economic Policy Uncertainty(GEPU) is a very important issue in policymaking by a country's economic decision-makers. Also, it is important for bank managers in their management and can directly increase banks' credit risk and worsen the performance of these economic institutions. In other words, economic policy uncertainties could affect the performance of banks.

[1] Gross Domestic Product

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One of the performance measurements in banks is the NPL ratio (Louri and Karadima, 2020). Therefore, it is significant to evaluate the relationship between GEPU and NPL to determine how many economic uncertainties could affect banks' performance.

Evaluation of the conditional correlation between the two indicators of Global Economic Policy Uncertainty (GEPU) and Non-Performing Loans (NPLs) has been performed in the banking system of different countries (Louri and Karadima, 2020). Since this issue has not been studied in Iran, as a developing country, we tried to evaluate the correlation between these two indicators based on the Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity Model (DCC-GARCH). The importance of studying this issue in Iran is that it allows the Central Bank of Iran[1] to make proper policies and regulations, and the CEOs of Iranian banks to make precise strategies to deal with shocks and critical situations, and it becomes clear to them whether the banking system is affected by global shocks. This question becomes important when a supervisory entity (CBI) seeks to adopt policies in crises, such as quantitative easing policies, non-standard monetary policy, or decreasing interest rate to deal with a crisis and prevent potential losses. This subject will be more important when we know that Iran's economy, especially the banking system, is under severe economic sanctions and other characteristics that made Iran's banking system completely separate from the International banking system.

In this study, we try to evaluate the Dynamic Conditional Correlation between the two indicators of Global Economic Policy Uncertainty (GEPU) and Non-Performing Loans (NPL) in the Iranian banking system; for this reason, we will use the Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity Model (DCC-GARCH) based on previous researches. Iran's banking system has been under banking and economic sanctions since 2012 for several years, especially after 2017; the question that can be raised is whether, despite these sanctions, the Global Economic Policy Uncertainty (GEPU) in the world can still affect the performance of Iranian banks. We seek to determine how much international uncertainty and irregularities can affect the performance of Iranian banks and the Iranian banking system. Evaluating this correlation based on the assessment of non-performing loans (NPLs) in different banks means that risk managers should be fully aware that they are not immune to external shocks in the Iranian banking system.

[1] CBI

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2 Literature Review

One of the concepts related to economic fluctuations is the concept of economic policy uncertainty that affects economic activities and financial stability (Junttila and Vataja, 2018). In recent years, concerns about Economic Policy Uncertainty (EPU) and the impact of economies on each other, the global financial crisis, and political crises have been the focus of researchers and policymakers. Because on the one hand, the economies of different countries seek closer ties with the global economy. On the other hand, the dynamics of international markets also affect countries' economies (Liu et al., 2019).

Economic Policy Uncertainty (EPU) refers to instability caused by changes in government economic policies and may cause delays or changes in important decisions such as employment, investment, consumption, savings by firms, and other economic factors. Therefore, the economy faces the costs of economic instability (Haidarpour and Pourshahabi, 2012). Various ways have been proposed to measure and examine the Economic Policy Uncertainty (EPU) index. The first way is to study the volatility of stock markets, which determines the amount of these volatilities in the relevant horizons in a certain period. Another way is based on newspaper and various economic and public reports review. One way to calculate the Economic Policy Uncertainty (EPU) index is to measure and examine the number of words used in newspapers and economic and public reports significantly associated with uncertainty. The purpose of obtaining and examining this index is to gain a perspective for economic decisions by investors and to implement various economic policies for the future. Finally, another way to measure Economic Policy Uncertainty (EPU) is to use Twitter software. For this purpose, all tweets are posted that check the words related to economics and uncertainty, and this index is measured (Baker, 2016).

The Global Economic Policy Uncertainty (GEPU) index is the international EPU index, the weighted average of the Economic Policy Uncertainty (EPU) index of the sixteen developed countries in the world. The GDP of these sixteen countries comprises about 70% of the world's gross domestic product. It shows the level of economic uncertainty and investor confidence in economic indicators for future investment (Fang et al., 2018). Numerous studies have been conducted to examine the effects of GEPU on important economic indicators. A study has shown that increasing this index can lead to a severe recession (Bloom, 2017). Another study states that the GEPU index can influence important economic policies, including liquidity risk policies in BRIC countries (Demir and Ersan, 2017).

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There are other indicators that can help us, such as World Pandemic Uncertainty Index (WPUI) and Monetary Policy Uncertainty (MPU). World Pandemic Uncertainty Index (WPUI) examines pandemic uncertainty differently from World Uncertainty Index (WUI). The World Pandemic Uncertainty Index (WPUI) function is to measure the number of times the word "uncertainty" is used in connection with various pandemics, such as Ebola and COVID-19, in various reports. Like the Economic Policy Uncertainty (EPU) index, this index is a criterion for foreign and domestic investors in deciding on the future. If the World Pandemic Uncertainty Index (WPUI) increases, the pandemic uncertainty will be greater. For example, one of the pandemics that affected the world's economic policies was the COVID-19 pandemic, which was able to disrupt many economic activities (Ho and Gan, 2021). Monetary Policy Uncertainty (MPU) index is another indicator that foreign and domestic investors pay a lot of attention to and regulate their economic activities so that this indicator is at its lowest possible level; By considering this index, these people seek to transfer various economic shocks to another time in the distance (De Pooter et al., 2021).

Nguyen (2021) has tried to evaluate the relationship between the Economic Policy Uncertainty (EPU) index and the stability of banks in different situations by examining more than 900 European banks during the period from 2005 to 2014. In this study, the research method was GMM regression. The results show that with increasing Economic Policy Uncertainty (EPU), the stability of banks decreases and vice versa. This paper examines the effects of different policies and supervision on the relationship between Economic Policy Uncertainty (EPU) and bank stability. The results of the article show that by increasing supervision and applying appropriate regulations, unrelated activities in banks can be prevented so that the risk indicators in the bank do not increase and do not cause instability in banks (Nguyen, 2021).

Louri and Karadima (2020) examined the impact of the Economic Policy Uncertainty (EPU) Index on the Non-Performing Loan (NPL) and the concentration of 500 banks in four countries: France, Germany, Italy, and Spain from 2005 to 2017. These banks have faced many problems after the great financial crisis, and important factors such as Economic Policy Uncertainty (EPU) have had a significant impact on their performance. One of the biggest problems for banks has been the Non-Performing Loan (NPL). The results show that Economic Policy Uncertainty (EPU) affects the Non-Performing Loan (NPL) but shows that if a bank's performance with a high EPU is negatively affected, by applying the centralization policy by bank managers, the losses can be compensated, and the performance of banks

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Improve. It means that the effects of the Economic Policy Uncertainty (EPU) can be adjusted by focusing on surviving unfavorable economic conditions in countries where the Economic Policy Uncertainty (EPU) is not appropriate (Louri and Karadima, 2020).

Al-Thaqeb et al. (2020) studied the impact of COVID-19 and the impact of Economic Policy Uncertainty (EPU) on the global economy caused by this pandemic. This study also examines the impact of various factors such as war or severe recessions such as 2008 on the Economic Policy Uncertainty (EPU) index. Also, they evaluated the effects of high Economic Policy Uncertainty (EPU) on society, households, companies, governments, or various markets. Finally, they illustrated the importance of risk management in managing uncertainties that may occur at different times in a society or economy.

Athari (2020) assessed the impact of factors such as Economic Policy Uncertainty (EPU) on bank profitability in Ukraine from 2005 to 2015. Using an experimental model that tests the factors affecting the profitability of banks, this study has been able to determine the impact of factors such as Economic Policy Uncertainty (EPU) on the profitability of banks in Ukraine. The results of this study indicate that when the economic policy uncertainty index decreases, it causes banks' profitability to grow, but it is also stated that profitability is partly related to the type of industry and the performance of bank managers. These results show that bank managers should manage banks and increase their profitability in an environment with less risk and less economic uncertainty by using models that increase revenue diversification and reduce internal risk.

Njindan Iyke (2020) looked at how the COVID-19 Pandemic impacted the economies of Asian countries (the top five in Asia: China, India, Japan, South Korea, and Singapore) and what changes have taken place in the Economic Policy Uncertainty (EPU). In this study, a regression model has been used, and the results have shown that the situation of China and South Korea has improved and the Economic Policy Uncertainty (EPU) index has decreased. In the other three countries, India, Japan, and Singapore, the Economic Policy Uncertainty (EPU) index has increased significantly in 2020, which can only be due to the pandemic spread of Quid 19 in the world and its impact on the economies of different countries in the world and Disrupt global trade. Finally, it has been stated that expansionary policies can be appropriate policies to reduce the destructive effects of this pandemic so that countries' economies can be moved in a direction that does not cause significant damage to them and economic activities resume.

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Bagherzadeh et al. (2020) studied the effect of the Economic Policy Uncertainty (EPU) of government on economic growth in terms of financial market development from 1978 to 2018 using a nonlinear model. In this research, to estimate the uncertainty, the new model of Generalized Self-Regression score has been used, and to estimate the uncertainty effect of government expenditure on economic growth in terms of capital market development, the Smooth Transition Self-Regression model has been used. This study shows that the uncertainty of government spending at low levels of investment has a negative effect and at high levels of investment has a positive effect on economic growth.

Ashna and Lal (2020) investigated the effect of Global Economic Policy Uncertainty (GEPU) on stock market fluctuations, gold fluctuations, and foreign exchange fluctuations in Iran. In this paper, the correlation of the mentioned variables in Iran with the Global Economic Policy Uncertainty (GEPU) index is investigated by the GARCH dynamic conditional correlation model (DCC-GARCH) and using monthly data of Tehran Stock Exchange price index, gold coin price, and foreign exchange rate for the period April 2002 to March 2017. The results show that Global Economic Policy fluctuations significantly affect stock market fluctuations, gold coins fluctuations, and foreign exchange fluctuations. Another issue that emerges from the results of this study is that this index has a positive effect on the fluctuation of gold coin prices in most cases and has a positive and negative effect on the stock market and foreign exchange fluctuations. Finally, it is concluded that the Global Economic Uncertainty index is useful in predicting fluctuations in these markets and can improve the forecast of stock, gold, and foreign exchange fluctuations.

Nguyen et al. (2019) attempted to assess the impact of the Economic Policy Uncertainty (EPU) index on the Aggregate Banks Credit in 22 countries between 2001 and 2015. In this research, a panel model has been used. The results show that if the Economic Policy Uncertainty (EPU) increases, it will reduce Aggregate Banks Credit, which can be a very important point for bank managers to manage the performance of banks; Contrary to the above result, it is also confirmed in the article that reducing the Economic Policy Uncertainty (EPU) causes a significant increase in bank credit. Finally, and presents another very important conclusion: countries with emerging economies are always more exposed to Economic Policy Uncertainty (EPU) risks than advanced countries, and even more severe.

Tao and Xu (2019) evaluated the relationship between Economic Policy Uncertainty (EPU) and Bank Credit using a panel regression model. This

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relationship was tested on 142 banks using data from 2007 to 2016. The article stated that various events are taking place in the world that increase Economic Policy Uncertainty (EPU) and discourage investors about the future. The results show that when the Economic Policy Uncertainty (EPU) index increases, Bank Credit declines, and vice versa. Finally, it states that the Economic Policy Uncertainty (EPU) has less impact on public economic institutions and banks (Tao and Xu, 2019).

In Amiri and Pirdadeh (2019), the effect of Economic Policy Uncertainty (EPU) on Stock Market Returns has been investigated using linear and nonlinear models (Markov switching) during the period 1981 to 2016. In the above research, the variables of Economic Growth rate, Inflation rate, Unemployment rate, Real Interest rate, Economic Policy Uncertainty and Liquidity Growth rate are used as independent variables. Findings show that uncertainty in Economic Policies reduces Stock Market Returns. Also, the relationship between Stock Market Returns and uncertainty of nonlinear economic policies and the effect of uncertainty on Stock Returns is stronger and more stable in a regime with high fluctuations.

Rezaei and Norouzi (2019) examined the impact of Economic Uncertainty on credit risk, performance, and banks' lending decisions. For this purpose, the variables affecting banks' lending decisions were first divided into three indicators (credit risk, performance, and lending rate); Economic Uncertainty is also measured using the standard deviation of six variables (Foreign Exchange rate, Annual Interest rate, GDP, National Income Growth rate, Oil Sales ratio to National Income, Tax to National Income ratio); Then, the research data have been collected in the period of five years from 2011 to 2015 for nine banks listed on Tehran Stock Exchange and have been examined using three different econometric models. The results showed that the economic uncertainty variable has a positive and significant effect on banks' credit risk in the first model. In the second model, economic uncertainty had a positive effect on the performance of banks, and finally, in the third model, no significant relationship was found between economic uncertainty and the amount of bank lending.

Mirzaei and Sheikh (2018) stated that Economic Policy Uncertainty (EPU) can affect economic growth, reduce stock returns and investment of companies, and increase cash capital. In this study, the main purpose was to investigate the effect of Economic Policy Uncertainty (EPU) on the tax burden of companies listed on the Tehran Stock Exchange during the period 2012 to 2018. In this research, a panel data model has been used to analyze the

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collected data. Findings showed that economic policy uncertainty had significant effects on the tax burden of companies.

Baker et al. (2016).attempted to measure the Economic Policy Uncertainty Index (EPU) for the economies of the United States and eleven other countries. This study used the frequency of the newspaper coverage index to examine the economic policy uncertainty index (EPU). This index has been evaluated near important historical events. The results showed that increasing the economic policy uncertainty index (EPU) causes financial instability, increases unemployment, and reduces community investment. This study investigated the effect of economic uncertainty on important economic indicators such as unemployment, production, and investment. This study has been reviewed for many years and the article emphasizes that newspapers have been available in these twelve countries. The research method was to evaluate how to use newspaper archives to analyze the policies that economic managers apply to increase the productivity of economic institutions. In addition, the researchers used newspaper articles to create indicators of economic policy uncertainty for large economies. In calculating the economic policy uncertainty index, this study considered possible concerns about newspapers' reliability, accuracy, bias, and compatibility. In calculating the EPU, the newspaper archives were examined, and a number of articles containing the words related to the three categories of uncertainty, economics, and politics were counted.

Recently, the solutions for financial restructuring in Iranian banks have been investigated by Abdullahi Poor et al. (2020). The first step was implementing the Asset Quality Review (AQR) based on the IMF[1] guideline. They showed the importance of the connection between Iran's banking system and the global one. Moreover, Abdollahi Poor et al. (2021) showed that internal macroeconomic indicators affect an important economic performance indicator, named RAROC[2], in Iranian Banks

Also, in Salem et al. (2019), the effect of Economic Uncertainty criteria on Earnings Management based on accruals and Real Earnings Management in companies listed on the Tehran Stock Exchange has been evaluated. In this study, to measure economic uncertainty, four variables include GDP growth, Inflation rate, Foreign Exchange rate, and Interest rate, have been used using in ARCH and GARCH models. For this purpose, four hypotheses have been compiled to investigate this issue. Data related to 241 listed companies of the

[1] International Monetary Fund
[2] Risk-Adjusted Return on Capital

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Tehran Stock Exchange were analyzed between 2007 and 2016. The results showed that the criteria of Economic Uncertainty (GDP Growth, Inflation rate, Foreign Exchange rate, and Interest rate) have a positive and significant effect on Earnings Management based on accruals. In addition, the results showed that the criteria of Economic Uncertainty (GDP Growth, Inflation rate, Foreign Exchange rate, and Interest rate) have a positive and significant effect on Real Earnings Management.

3 Methodology and Research Model

3.1 Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroscedasticity Model (DCC-GARCH)

Engle (1982) showed that patterns can be considered that include both conditional mean and conditional variance. These patterns became known as Autoregressive Conditional Heteroskedasticity (ARCH) patterns, which are based on the Heteroskedasticity in the model under study. In such cases, it is expected that the variance is not constant during the random process of the variable and is a function of the behavior of the error sentences. Autoregressive Conditional Heteroskedasticity (ARCH) patterns were generalized by Ballerslev (1986) under the title Generalized Autoregressive Conditional Heteroskedasticity (GARCH). In general, the basic equation of GARCH (p, q) can be expressed as follows:

$$Y_t = \mu_t + \sigma_t z_t \,,\; z_t \sim NID\ (0,1)$$
$$\mu_t = a + \sum_{i=1}^{k} b_i X_{i,t} \qquad (1)$$
$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \cdots + \alpha_q \varepsilon_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \cdots + \beta_p \sigma_{t-p}^2 = a_0 + \sum_{i=1}^{q} a_i \varepsilon_{t-1}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-1}^2,\; \varepsilon_t \sim NID\ (0, H_t) \qquad (2)$$

In Equation (1), Y_t is the Conditional Mean that depends on the explanatory variables and their coefficients. In this equation, X_i contains explanatory variables that include exogenous variables and endogenous variables with different intervals and z_t is also a component of the perturbation that has the same independent distribution. The process of positive fluctuations is determined by H_t which is obtained by different Autoregressive Conditional Heteroskedasticity (ARCH) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models.

An important condition that must always be met is that the sum of parameters α_q and β_p must be less than one ($\alpha_q + \beta_p < 1$).

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In order to investigate the correlation between economic variables over time, dynamic multivariate conditional Heteroskedasticity models are used. One of the important features of these models is the dynamic estimation of the conditional variance-covariance matrix between the variables and then the dynamic correlation between them. The Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity Model (DCC-GARCH) model has advantages over other estimation methods. This model detects changes in conditional correlations over time and allows identifying the investor's dynamic behavior in response to news and various changes (Rajwani and Kumar, 2016). Also, this model allows us to consider additional explanatory variables in the mean equation to ensure the goodness of fit of the model (Chittedi, 2015). According to experimental studies conducted by Bollerslev (1992), Engle (2002), and Engle and Sheppard (2001), the multivariate Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity Model (DCC-GARCH) model is as follows:

$$r_{it} = \phi_{i0} + \phi_{i0}\, r_{it-1} + \varepsilon_{it}, \qquad \varepsilon_t = H_t^{\frac{1}{2}} u_t, \quad \varepsilon_t : N(0, H_t) \tag{3}$$

$$h_{it} = \omega_i + \delta_i\, \varepsilon_{it-1}^2 + \gamma_i\, h_{it-1} \tag{4}$$

Where standardized remainder is $z_{i,t}$ and h_{it} is the conditional variance.

$$H_t = D_t\, R_t\, D_t \tag{5}$$

H_t is a conditional covariance matrix 2 × 2, R_t *is* a conditional correlation matrix and D_t *is* a diagonal matrix with variable-time standard deviation.

$$D_t = \{diag\,(H_t)\}^{\frac{1}{2}}, \;\; if : i = 1,2 \longrightarrow D_t = \begin{bmatrix} \sqrt{h_{11t}} & 0 \\ 0 & \sqrt{h_{22t}} \end{bmatrix} \tag{6}$$

$$R_t = diag\left((Q_t)^{-\frac{1}{2}}\right) Q_t\, diag\left((Q_t)^{-\frac{1}{2}}\right) \tag{7}$$

Where Q_t is the positive defined symmetric matrix 2 × 2 and $Q_t = (q_t^{ij})$ as follows:

$$Q_t = (1 - \theta_1 - \theta_2)\bar{Q} + \theta_1 z_{t-1} z'_{t-1} + \theta_2\, Q_{t-1} \tag{8}$$

The 2×2 matrix is an unconditioned correlation of standardized remainders. θ_1 and θ_2 are non-negative parameters that satisfy the condition $\theta_1 + \theta_2 < 1$. The constraints expressed for parameters θ_1 and θ_2 ensure that Q_t is definite and positive, and this is a necessary and sufficient condition for

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the R_t matrix to be definite (Engle and Sheppard, 2001). The correlation coefficient is estimated as follows:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}\, q_{jj,t}}} \quad (9)$$

The diagonal Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model assumes that the dynamic correlation is zero, so that $\rho_{ij,t} = 0$ are established for all values of i and j. On the other hand, it also considers the fixed conditional correlation as $R_{ij} = \rho_{ij}$ and $R_t = R$ (Rajwani and Kumar, 2016).

3.2 Conditional Correlation Stability Test

For the conditional correlation stability hypothesis, a test has been proposed by Engle and Sheppard (2001), whose null hypothesis expresses the correlation stability, and the opposite hypothesis is the conditional correlation dynamics.

$$H_0 : R_t = \bar{R} \Longrightarrow CCC\ Model$$
$$vech^u\,(R_t) = vech^u\,(\bar{R}) + \beta_1 vech^u\,(R_{t-1}) + \beta_2 vech^u\,(R_{t-2}) + \cdots + \beta_p vech^u\,(R_{t-p}) \quad (10)$$

Initially, the univariate Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model and standardized residuals are estimated for each time series. Then, the correlation between the residues is estimated and the vector of the univariate residuals is standardized using Symmetric Square Root Decomposition of the correlation matrix (R). Under the null hypothesis that the correlation is constant, the residues must have a uniform distribution (Engle and Sheppard, 2001).

4 Model Estimation and Results Analysis

4.1 Descriptive Statistics

Table 1 shows the descriptive statistics of the research. Data of Non-Performing Loans (NPL) is extracted from the monthly reports of the Central Bank of Iran for the entire banking system. In this table, it is specified that the Non-Performing Loans (NPL) index data varies from 0.053855 to 0.221852. The average of these numbers is 0.129099, which has grown significantly in critical periods and major financial crises. Global Economic Policy Uncertainty (GEPU) data is extracted from reports at policy uncertainty

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institution[1]. The table also shows that the data of the Global Economic Policy Uncertainty (GEPU) index varies from 48.89635 to 430.0177, and the average of these numbers is 143.3587, which means that this index has grown significantly in critical periods and major global crises such as COVID-19 pandemic and the financial crisis in 2008; For example, the maximum Global Economic Policy Uncertainty Index (GEPU) occurred in the third month of 2020 due to the COVID-19 pandemic and reached a very high number of 430.0177, which over time, at the end of the sixth month of 2021, approached 180. In this paper, R and Eviews programming and statistical software have been used to analyze the mentioned data and run the research model.

Table 1
Descriptive Statistics of the Research Variables

Description	**NPL ratio (Iranian Banks)**	**GEPU**
Mean	0.129099	143.3587
Median	0.129091	126.3215
Maximum	0.221852	430.0177
Minimum	0.053855	48.89635
Std. Dev.	0.037501	72.73563
Skewness	0.120577	1.215927
Kurtosis	2.742137	4.358247
Observations	210	210

The following diagram presents the approximate NPLs of selected banks listed in the Tehran Stock Exchange[2] in the last decade.

[1] www.policyuncertainty.com
[2] TSE

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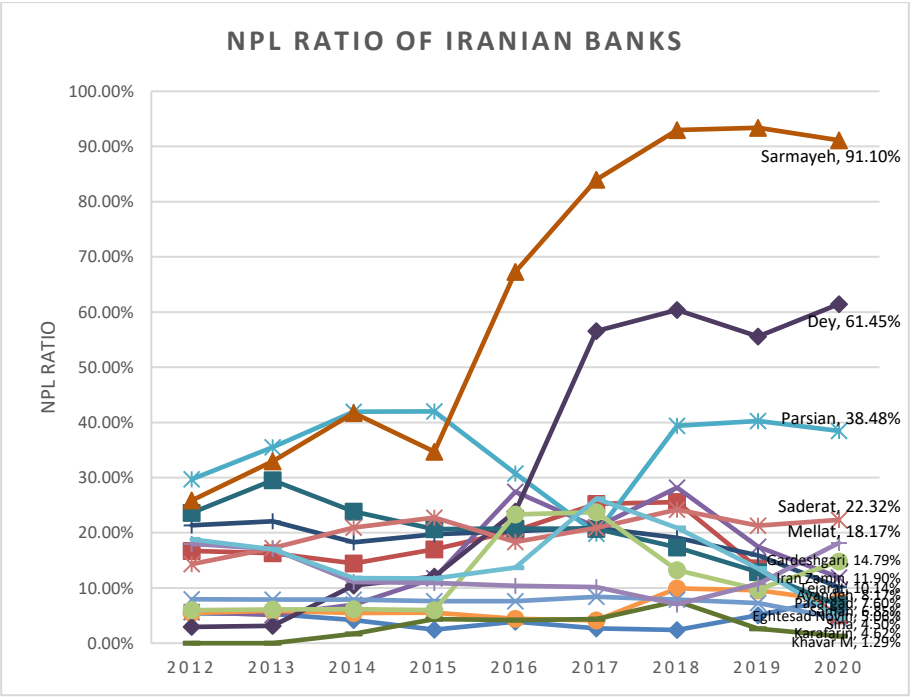


Figure 1. NPL Ratio of Iranian Banks registered in Tehran Stock Exchange

The highest NPL ratio in 2020 is related to Sarmayeh Bank with 91.1 percent, and the least is for Khavarmiyaneh Bank by just 1.29 percent.

4.2 Dynamics of Global Economic Policy Uncertainty (GEPU) and NPL

The time series diagrams of the Non-Performing Loans (NPL) and Global Economic Policy Uncertainty (GEPU) show the variables' mean (figure 2 and 3) and variance (figure 4 and 5) during the sample period 2004 to 2021. The Global Economic Policy Uncertainty (GEPU) index rose sharply in 2008 due to severe financial crises, approaching 205, and the Non-Performing Loans (NPL) index has fallen sharply in the same year, approaching 0.06. The Global Economic Policy Uncertainty (GEPU) index has fluctuated in different years for various reasons, but in 2020, due to the COVID-19 pandemic, it fluctuated very sharply and had an unprecedented growth that reached close to 430. The Non-Performing Loans (NPL) index has also experienced several fluctuations,

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but from 2008 to 2010, it had a significant growth after the financial crisis of 2008 and has been declining with a reasonable slope since then. The low similarity between Figures 1 and 2 indicates a low level of correlation between these two indicators. The time series diagrams of Global Economic Policy Uncertainty (GEPU) and Non-Performing Loans (NPL) indices are shown in Figures 2 and 3.

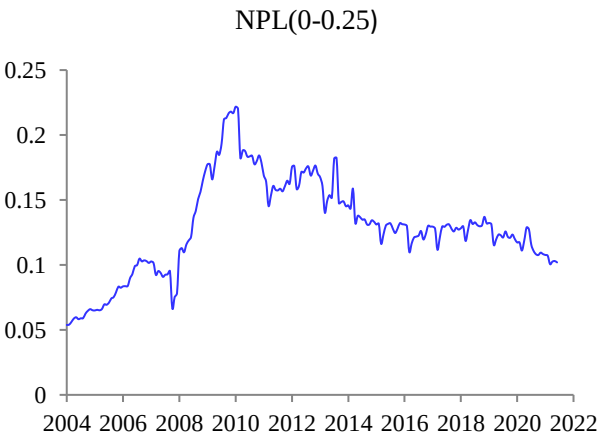


Figure 2. Monthly Non-Performing Loans (NPL) Ratio of Iranian Banks.

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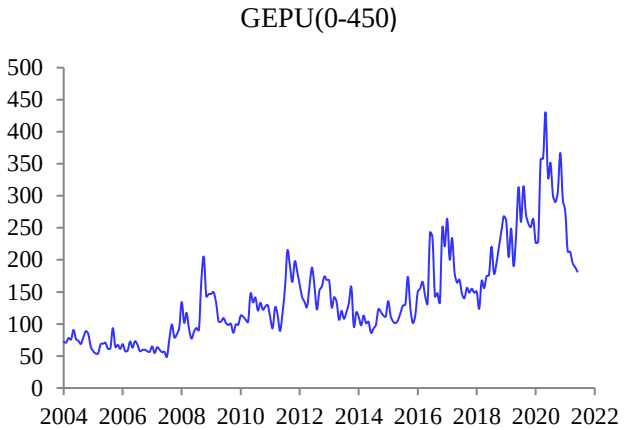


Figure 3. Monthly Global Economic Policy Uncertainty (GEPU).

The return series diagram means a return with volatility clustering. The return volatility of the Non-Performing Loans (NPL) index is relatively lower than Global Economic Policy Uncertainty (GEPU) index. Therefore, the preliminary results show that it is better to use the Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroscedasticity Model (DCC-GARCH) model to obtain the return series diagrams. Return series diagrams are shown in Figures 4 and 5.

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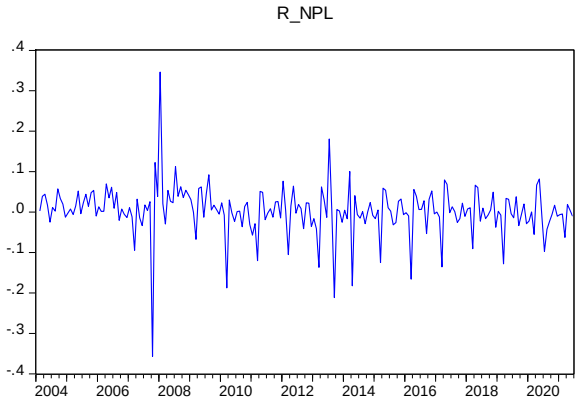


Figure 4. Monthly Non-Performing Loans (NPL) variation of Iranian Banks.

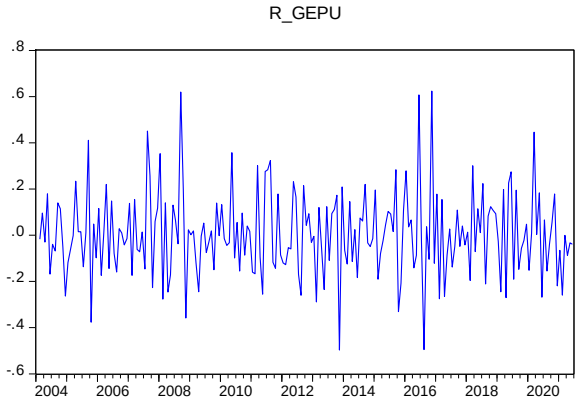


Figure 5. Monthly Global Economic Policy Uncertainty (GEPU) variation.

4.3 Stationarity and Residual Diagnostic Tests

To check the Stationary of the variables, the Augmented Dickey-Fuller (ADF) Unit Root Test was used. The results of the Unit Root Test show that all variables are at a stable level (Table 2).

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Table 2
Results of the Augmented Dickey-Fuller (ADF) Unit Root Test

Test	t-Statistic	Prob.
Null Hypothesis: R_GEPU has a unit root		
Augmented Dickey-Fuller test statistic	-17.92428	0.0000
Null Hypothesis: R_NPL has a unit root		
Augmented Dickey-Fuller test statistic	-15.41461	0.0000

4.4 Correlation Matrix

Table 3 shows the correlation matrix results between Global Economic Policy Uncertainty (GEPU) and Non-Performing Loans (NPL) of Iranian Banks indices. In this table, all values are positive, indicating that these two indicators are moving in the same direction. However, the correlation between these two indicators is 0.0273, which indicates low co-movements and the absence of multicollinearity (Vo and Ellis, 2018). In this paper, an attempt has been made to obtain a higher accuracy correlation using the DCC-GARCH model.

Table 3
Correlation Matrix

Correlation	R_GEPU	R_NPL
R_GEPU	0.032822	
	1.000000	
R_NPL	0.000301	0.003713
	0.027312	1.000000

4.5 DCC-GARCH Model

Conditional correlation model estimation is done in two steps. In the first step, a GARCH model is selected for conditional variance, and then the conditional correlation matrix based on conditional variance is obtained, and Engle and Sheppard Test (2001) are used to check and validate the DCC model.

The Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroscedasticity Model (DCC-GARCH) model diagnostic test is determined from the Constant Conditional Correlation Generalized Autoregressive Conditional Heteroscedasticity Model (DCC-GARCH) models by the statistics of Engle and Sheppard Test (2001). However, according to the correlation diagram between the variables and the estimation of α and β parameters, which are less than one, it can be concluded that the

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DCC (1,1)-GARCH (1,1) model is correct. Two DCC-GARCH models with Gaussian have been used to compare based on the maximum likelihood values.

Table 4
Results of DCC-GARCH Model Estimation

Model	DCC-GARCH
Alpha	0.1885
Beta	0.8034
1-(Theta1+Theta2)	0.0081
Maximized Log-Likelihood = −26,554.0	

According to Table 4, the estimation results of GARCH model (1,1) show that the α and β parameters are non-negative and significant and the condition $\alpha + \beta < 1$ is also met. Also, the correlation stability test results using Engle and Sheppard Test (2001) indicate the rejection of the null hypothesis that the conditional correlation is constant over time. As a result, a model should be used that considers the conditional correlation over the time of the variable. With being positive α, an increase can be expected in the conditional correlation for the next period following a shock in a series of variables. The parameter β expresses the effect of the conditional correlation of the previous period on the current period. Suppose this parameter is larger and closer to one. In that case, the current period conditional correlation is expected to be close to the previous period conditional correlation for each pair of calculated correlations.

4.6 The Plots of Conditional Correlation and Conditional Volatility

Figure 6 shows the values of Conditional Volatilities of Monthly returns of the two indices of Non-Performing Loans (NPL) index and Global Economic Policy Uncertainty (GEPU). The graph shown in Figure 6 is shown in terms of time and shows the state of fluctuations at each point in time. At the beginning of this diagram, volatility has grown and peaked in 2008 due to the financial crisis. Then, after this crisis, the fluctuations decreased significantly, and several fluctuations occurred with different intensities during the years 2008 to 2016, but in 2016, two sharp fluctuations occurred as severe as in 2008. In 2020, there was a sharp fluctuation due to the COVID-19 pandemic, which was not as severe as the fluctuations in 2008 and 2016.

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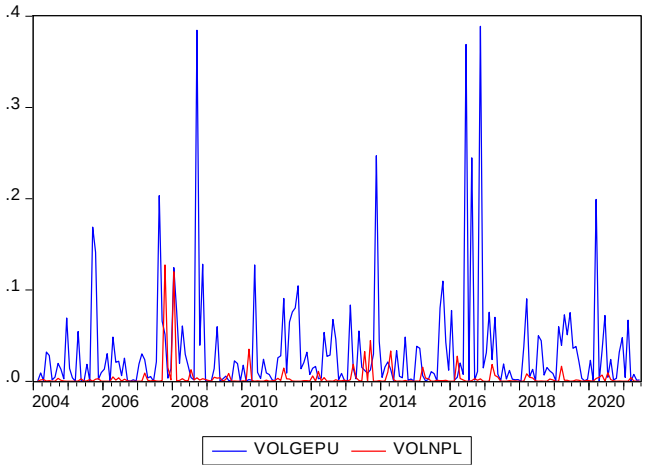


Figure 6. A Plot of Conditional Volatilities of Monthly Data.

Figure 7 shows the conditional correlation between Non-Performing Loans (NPL) and Global Economic Policy Uncertainty (GEPU) indices. This figure shows the similarity of conditional and unconditional correlation results between these two indicators. The lines representing the volatility of the Non-Performing Loans (NPL) index and Global Economic Policy Uncertainty (GEPU) are along with the graph are along with the graph. Some lines cross the zero point and show less correlation. However, when important events have taken place in the world, and severe shocks have hit the world financial markets and banking system, the movements near the correlation lines have increased, such as 2008, 2016, and 2020 and the correlation has been growing between these two indicators.

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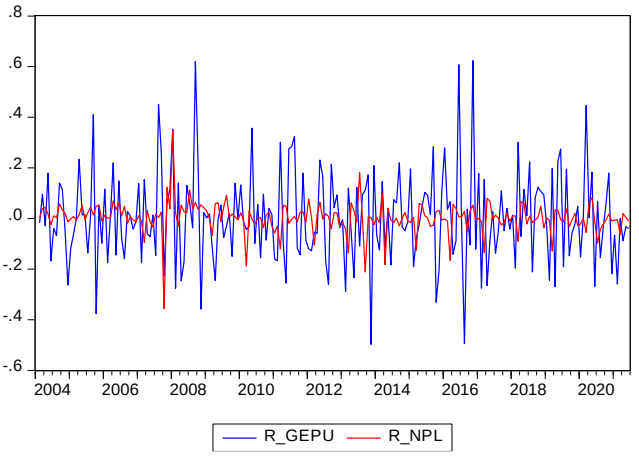


Figure 7. Plot of conditional correlations of GEPU and NPL.

To sum up, although the Iranian banking system is responding to global crises and is somewhat affected by international economic uncertainties, these results suggest that, due to the low level of communication between Iranian banks and the international banking system and global markets, this relationship is insignificant after the imposed sanctions in 2012 and 2017. The reasons for this weak connection may be mostly due to international sanctions against the Iranian economy and banks in recent years, imposed loans to the bank by the internal government, forced interest rates, etc. These restrictions have made the Iranian banking system less sensitive to global dynamics, and by limiting their access to foreign resources and markets, a kind of "isolation" has been created for Iranian banks, and while depriving Iranian banks of all benefits, they are largely immune to global economic shocks. According to Figure 6, the correlation between the two indicators had decreased, while before 2012, this correlation was higher. This can be due to many economic reasons and events in Iran, but it seems that this decrease in correlation between these two indicators was due to the intensification of sanctions on the Iranian economy and banking system in 2012; In other words, the Non-Performing Loans of Iranian banks or the functioning of the Iranian banking system have been more affected by global crises and uncertainties before economic sanctions.

To prove this claim, we evaluate the correlation between GEPU and NPL ratio of some other countries with an open economy, such as Japan, Singapore,

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the USA, Turkey, and Spain. The results show that the mentioned correlation is meaningfully higher than Iran, nearly 0.33 to 0.58. The following Table clarifies the results.

Table 5
Correlation Matrix

	R_GEPU	**R_NPL_JAPAN**	**R_NPL_SINGAPORE**	**R_NPL_SPAIN**	**R_NPL_TURKEY**	**R_NPL_USA**
R_GEPU	1.000000	0.580932	0.407341	0.388593	0.334039	0.428124
R_NPL_JAPAN	0.580932	1.000000	0.240677	0.499177	0.576982	0.602086
R_NPL_SINGAPORE	0.407341	0.240677	1.000000	0.064801	0.103000	0.112577
R_NPL_SPAIN	0.388593	0.499177	0.064801	1.000000	0.050736	0.630549
R_NPL_TURKEY	0.334039	0.576982	0.103000	0.050736	1.000000	0.194228
R_NPL_USA	0.428124	0.602086	0.112577	0.630549	0.194228	1.000000

Also, a DCC-GARCH model has been run for all the mentioned countries and the estimation results of the GARCH model (1,1) show that the α and β parameters are non-negative and significant and the condition $\alpha + \beta < 1$ is also met. The detailed output has been reported in Table 6.

Table 6
Results of DCC-GARCH Model Estimation for other countries

Model: DCC-GARCH	**Japan**	**Singapore**	**USA**	**Turkey**	**Spain**
Alpha	0.1835	0.0638	0.1196	0.4712	0.0054
Beta	0.2718	0.9101	0.8121	0.1907	0.7836

It declares that there should be some factors in the Iranian banking system which are not in existence in other open economies. These factors could be related to comprehensive economic sanctions and other important differences like the internal government's imposed loans to the bank, forced interest rates, etc. To be exact, the intervention of Iran's government in different parts of the economy, especially the banking system, is noticeable compared to other countries. They often press the Central Bank of Iran and Money and Credit

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Council to make decisions based on political observations. For example, they impose banks to give loans and facilities to people without credit validation or scoring. Moreover, they sometimes try to affect the Money and Credit Council decisions about interest rates of different deposits, deposit maturity, etc.

5 Conclusions

Nowadays, economic policymakers of different countries pay a lot of attention to the Global Economic Policy Uncertainty (GEPU) index to prevent losses caused by various shocks in different investments in different countries and their performance in managing financial markets and the banking system.

In this paper, the Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroscedasticity Model (DCC-GARCH) is used to investigate the relationship between Global Economic Uncertainty and the Non-Performing Loans of Iranian banks as a proxy for the soundness of the banking system. The model records the fluctuations and correlations of these two indicators in each period, which helps to find the right analysis after the shocks created in the world, for example, the COVID-19 pandemic. This paper shows that Non-Performing Loans of Iranian banks correlate with Global Economic Uncertainty during major global shocks such as the global financial crises or the Covid-19 pandemic. Despite fluctuations in the correlation between Non-Performing Loans (NPL) and Global Economic Policy Uncertainty (GEPU) over time, this study also shows that these correlations generally remain somewhat low in some periods.

We also evaluate the correlation between GEPU and NPL of some other countries with open economies. The results illustrate that compared to Iran, this correlation is considerably higher. Therefore, it seems that Iran's banking system will not be noticeably affected by global uncertainties or economic shocks. Therefore, the reason should be investigated in differences between Iran's banking system and other countries, like economic sanctions, imposed loans to banks by the government, forced interest rates, etc.

Finally, we strongly suggest that future research about the impact of international economic shocks on the performance of Iranian banks should shed light on the straight effect of sanctions or other deficiencies in the banking system to show how many deductions in economic sanctions or address other internal banking issues as mentioned above, could increase the correlation between this integration. This fact could help Iran's economic policymakers plan and appropriately react when they confront global economic shocks.

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Also, it is highly recommended that it should be assessed whether this weak correlation is disadvantageous or not. In other words, should the economic policymakers know that at least under current circumstances in Iran's economy, they do not have to make non-standard monetary policies according to global shock, will they be more successful in managing the country's economy? It seems that these suggestions for future studies could be a complementary part of this paper.

References

Abdollahi Poor, M.S, Botshekan, M.H. (2020). Solutions for Financial Restructuring in Iranian Banks. *Journal of Asset Management and Financing*, 8(4), 1-20. doi: 10.22108/amf.2020.119436.1473

Abdollahi Poor, MS, Botshekan, MH. (2021). Investigating the Impact of Macroeconomic Indicators on Risk-Adjusted Return on Capital (RAROC) of Registered Banks in Tehran Stock Exchange and Iran Farabourse. *Journal of Asset Management and Financing*, 9(2).

Al-Thaqeb, S.A., Algharabali, B.G.H., & Alabdulghafour, K.T. (2020). The Pandemic and Economic Policy Uncertainty. John Wiley & Sons Ltd, 10.1002/ijfe.2298.

Amiri, H., & Pirdadeh, M. (2019). Uncertainty of Iran's Economic Policies and Stock Market based on Markov's Approach. Scientific Journal of Financial Knowledge of Securities Analysis, Year 12, No. 44.

Ashna, M., & Lal, H. (2020). Dynamic Correlation of Global Economic Policy Uncertainty Index with Stock Market, Foreign Exchange and Gold Market Fluctuations in Iran using GARCH Model. Econometric Modeling Quarterly, Year 5, No. 2: 147-172.

Athari, S.A. (2020). "Domestic Political Risk, Global Economic Policy Uncertainty, and Banks' Profitability: Evidence from Ukrainian Banks". Post-Communist Economies, https://doi.org/10.1080/ 14631377.2020.1745563.

Bagherzadeh, F., Mohseni, S.J., & Mansourfar, G.H. (2020). Nonlinear Relationship between Economic Policy Uncertainty of Government and Iran's Economic Growth with Emphasis on Financial Market Development using GAS Model. Quarterly Journal of Applied Theories of Economics, Year 7, Issue 2: 103-128.

Baker, SR., Bloom, N., & Davis, S.J. (2016). Measuring Economic Policy Uncertainty. NBER Working Paper, No. 21633.

Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroskedasticity. Journal of Econometrics, Vol. 3, Issue 3: 307-327.

Bollerslev, T., & Wooldridge, J.M. (1992). Quasi-Maximum Likelihood Estimation and Inference in Dynamic Models with Time-Varying Covariances. Econometric Reviews, 11: 143–172.

Bloom, N. (2017). Observations on uncertainty. Australian Economic Review, 50, 79–84.

[Downloaded from jme.mbri.ac.ir on 2026-10-30]

[DOI: 10.52547/jme.16.2.187]

Chittedi, K.R. (2015). Financial Crisis and Contagion Effects to Indian Stock Market: 'DCC–GARCH' Analysis. Global Business Review, 16(1): 50–60.

Demir, E., & Ersan, O. (2017). Economic policy uncertainty and cash holdings: Evidence from BRIC countries. Emerging Markets Review, doi:10.1016/j.ememar.2017.08.001.

De Pooter, M., Favara, G., Modugno, M., & Wu, J. (2021). Monetary Policy Uncertainty and Monetary Policy Surprises. Journal of International Money and Finance, Vol. 112, 102323.

Engle, RF. (1982). Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation. Econometrica, Vol. 50, No. 4: 987-1007.

Engle, R.F., & Sheppard, K. (2001). Theoretical and Empirical Properties of Dynamic Conditional Correlation Multivariate GARCH. NBER Working Paper, 8554.

Engle, R.F. (2002). Dynamic Conditional Correlation: a Simple Class of Multivariate GARCH Models. Journal of Business and Economic Statistics, 20(3): 339-350.

Fang, L., Chen, B., Yu, H., & Qian, Y. (2018). The Importance of Global Economic Policy Uncertainty in Predicting Gold Futures Market Volatility: a GARCH-MIDAS approach. Journal of Futures Markets, 38(3): 413–422.

Haidarpour, A., & Pourshahabi, F. (2012). Explaining the effects of economic uncertainty on macroeconomic variables (Case study: Iran). Quarterly Journal of Parliament and Strategy, 71: 125-148.

Ho, L.T., & Gan, C.H. (2021). Foreign Direct Investment and World Pandemic Uncertainty Index: Do Health Pandemics Matter? Journal of Risk and Financial Management, 14(3): 107, https://doi.org/10.3390/ jrfm14030107.

Junttila, J., & Vataja, J. (2018). Economic Policy Uncertainty Effects for Forecasting Future Real Economic Activity. Economic Systems, 42(4): 569–583.

Louri, H., & Karadima, M. (2020). Economic Policy Uncertainty and Non-Performing Loans: The Moderating Role of Bank Concentration. Finance Research Letters, https://doi.org/10.1016/j.frl.2020. 101458.

Li, T., Ma, F., Zhang, X., & Zhang, Y. (2019). Economic Policy Uncertainty and the Chinese Stock Market volatility: Novel Evidence. Economic Modeling, https://doi.org/10.1016/j.econmod.2019.07.002.

Liu, Y., Zheng, Y., & Drakeford, M. (2019). Reconstruction and Dynamic Dependence Analysis of Global Economic Policy Uncertainty. Quantitative Finance and Economics, 3(3): 550-561.

Mirzaei, H., & Sheikh, M.S. (2018). The Effect of Economic Policy Uncertainty on the Tax Burden of Companies Listed on the Tehran Stock Exchange. Economic Strategy Quarterly, Year 7, No. 24: 95-119.

Nguyen, C.P., Le, T.H., & Su, T.D. (2019). Economic Policy Uncertainty and Credit Growth: Evidence from a Global Sample. Research in International Business and Finance, https://doi.org/10.1016 /j.ribaf.2019.101118.

[Downloaded from jme.mbri.ac.ir on 2026-10-30]

[DOI: 10.52547/jme.16.2.187]

Nguyen, T.C. (2021). Economic Policy Uncertainty and Bank Stability: Does Bank Regulation and Supervision Matter in Major European Economies? Journal of International Financial Markets, Institutions and Money, Vol. 74, 101387.

Njindan Iyke, B. (2020). Economic Policy Uncertainty in Times of COVID-19 Pandemic. Asian Economics Letters, 1(2). https://doi.org/10.46557/001c.17665.

Rajwani, S., & Kumar, D. (2016). Asymmetric dynamic conditional correlation approach to financial contagion: a study of Asian markets. Global Business Review, 17(6): 1339-1356.

Rezaei, N., & Norouzi, A. (2019). Investigating Economic Uncertainty and Bank Lending Decisions. Quarterly Journal of Investment Knowledge, Year 8, No. 32.

Salem, B., Salehi, A.K., Jarjarzadeh, A., & Nasiri, S. (2019). Investigating the Effect of Economic Uncertainty on Accrual-Based Earnings Management and Real Earnings Management. Journal of Management Accounting and Auditing Knowledge, year 8, No. 30.

Tao, S.H., & Xu, M. (2019). The Impact of Economic Policy Uncertainty on Bank Credit Scale — An Empirical Study Based on Dynamic Panel System GMM Model. Open Journal of Business and Management, 7: 616-632.

Vo, X.V., & Ellis, C. (2018). International financial integration: Stock Return Linkages and Volatility Transmission between Vietnam and Advanced Countries. Emerging Markets Review 36: 19–27.

[Downloaded from jme.mbri.ac.ir on 2026-10-30]

[DOI: 10.52547/jme.16.2.187]