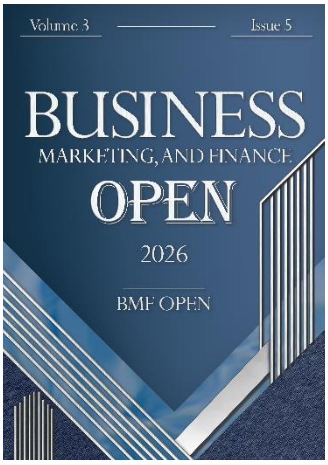
Threshold Effects of Financial Stress on the Relationship Between Oil Price Volatility and the COVID-19 Crisis on Stock Return Volatility in Pharmaceutical Companies Listed on the Tehran Stock Exchange



Negar Ehtemami [1], Lotf Ali Agheli [2,*] and Kambiz Peykarjou [3]

[1] Department of Economics and Management, SR.C., Islamic Azad University, Tehran, Iran;
[2] Department of Economics, Tarbiat Modares University, Tehran, Iran;
[3] Department of Economics and Management, SR.C., Islamic Azad University, Tehran, Iran;

* Correspondence: aghelik@modares.ac.ir

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Abstract: The present study aims to investigate the threshold effects of financial stress on the relationship between oil price shocks and the COVID-19 crisis on stock return volatility in pharmaceutical companies listed on the Tehran Stock Exchange. This study is applied in purpose and descriptive-analytical in nature, using an ex post facto design and panel data covering the period 2013–2024. The financial stress index (FSI) is constructed using Principal Component Analysis (PCA) based on nine macro-financial indicators across governmental, monetary, and exchange-rate sectors. Oil price shocks are extracted using the Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model to capture asymmetric volatility effects, while stock return volatility is estimated through ARMA-EGARCH modeling after confirming conditional heteroskedasticity using the ARCH test. The COVID-19 crisis is incorporated as a dummy variable. To analyze nonlinear relationships and regime-switching behavior, the Panel Smooth Transition Regression (PSTR) model with a logistic transition function is employed, where financial stress serves as the transition variable. Model validity is assessed through unit root tests (LLC), cointegration tests (Kao), linearity tests, and diagnostic checks for autocorrelation and heteroskedasticity. The results indicate that financial stress, COVID-19, oil price shocks, and inflation all have positive and statistically significant effects on stock return volatility. The linearity hypothesis is rejected, confirming the presence of nonlinear dynamics and regime-dependent relationships. The estimated threshold value of financial stress is significant, and the slope parameter indicates a relatively rapid transition between regimes. In the high financial stress regime, the effects of all explanatory variables intensify substantially, with financial stress showing the largest marginal impact on volatility. Oil price shocks exhibit asymmetric effects, with positive shocks generating greater volatility than negative shocks. The COVID-19 crisis significantly increases volatility, particularly under high financial stress conditions. Diagnostic tests confirm model adequacy, stability of parameters, and absence of econometric violations. The findings demonstrate that stock return volatility in pharmaceutical companies is driven by a nonlinear interaction of macroeconomic shocks and financial conditions, where financial stress acts as a critical threshold variable amplifying the effects of oil price volatility, inflation, and the COVID-19 crisis.

Keywords: Return volatility, COVID-19 crisis, oil shock, capital market, pharmaceutical companies.

1. Introduction

The volatility of stock returns in pharmaceutical companies has become an increasingly important research issue in recent years, especially in economies where capital markets are highly sensitive to macroeconomic shocks, health crises, and commodity-price instability. In such contexts, stock price dynamics do not arise solely from firm-level fundamentals; rather, they are shaped by a complex interaction among global disturbances, domestic uncertainty, financial market conditions, and sector-specific expectations. The pharmaceutical industry is particularly relevant in this regard because it occupies a dual position in the economy: it is both a strategic industry linked to public health and a market-sensitive industry exposed to financing conditions, exchange-rate movements, imported inputs, and investor sentiment. In emerging markets, and especially in Iran, these relationships may be even more pronounced because listed pharmaceutical firms operate under conditions of recurrent inflation, external sanctions, exchange-rate instability, oil dependence, and episodic financial stress. For this reason, understanding the determinants of stock return volatility in this sector requires an integrated framework that simultaneously considers health-related crises, oil-market shocks, and the broader financial environment [1-3].

The COVID-19 pandemic was one of the most disruptive global shocks of the modern era and generated widespread uncertainty across financial markets. Its impact was not limited to real-sector contraction; it also altered investor expectations, increased risk aversion, disrupted supply chains, and changed the pricing of assets across industries and countries. Stock markets reacted sharply to the pandemic through heightened volatility, sudden revaluations of risk, and changes in cross-sectoral capital allocation. For pharmaceutical companies, however, the effects of the pandemic were layered and in some cases contradictory. On the one hand, the health crisis increased the strategic relevance of pharmaceutical production, medical supply, and health-related innovation. On the other hand, it also intensified uncertainty regarding input costs, supply logistics, regulatory conditions, and investment horizons. Empirical studies on the pandemic's stock-market consequences show that COVID-19 significantly affected stock performance, return indices, and firm-level financial decisions, although the magnitude and direction of these effects varied by country, sector, and institutional environment [2, 4-6].

Within Iran's capital market, the COVID-19 crisis must be interpreted alongside pre-existing structural vulnerabilities. The Tehran Stock Exchange has long been influenced by inflationary episodes, exchange-rate shocks, oil-price movements, and waves of policy uncertainty. Therefore, the pandemic did not occur in isolation; rather, it interacted with a fragile macro-financial setting in which market participants were already highly responsive to external and domestic shocks. Comparative work on Iran's capital market suggests that the COVID crisis, much like the earlier global financial crisis, produced notable shifts in market behavior and intensified sensitivity to uncertainty [3]. Similarly, recent modeling efforts focused on Tehran Stock Exchange companies indicate that stock price indices are strongly affected by combinations of global financial turbulence, oil-price shocks, exchange-rate volatility, and pandemic-related disruptions [1]. These findings imply that any rigorous analysis of stock return volatility in listed pharmaceutical firms should treat COVID-19 not as a temporary exogenous dummy alone, but as part of a broader regime of amplified uncertainty.

Among the macroeconomic shocks that shape financial markets in oil-dependent economies, oil-price volatility remains one of the most consequential. Oil is not merely a traded commodity; in economies such as Iran, it is also a central source of fiscal capacity, foreign exchange earnings, macroeconomic stability, and investor expectations. Changes in oil prices can influence stock markets through multiple channels, including government spending, inflation, exchange rates, production costs, liquidity conditions, and future profitability. The literature has repeatedly shown that oil-price fluctuations affect returns, exchange rates, investment behavior, and market sentiment. In firm-level settings, oil-price instability can alter expectations about financing costs and sectoral profitability, even in industries that are not directly energy-producing. For pharmaceutical firms, which rely on imported raw materials, energy-intensive production, transportation networks, and regulated pricing environments, oil shocks may have indirect yet substantial effects on stock return volatility [7, 8].

The relevance of oil shocks becomes stronger when one considers the structural dependence of many emerging economies on resource revenues and imported intermediate goods. Oil-price increases can initially improve fiscal expectations in oil-exporting countries, but they may also intensify inflationary pressures, exchange-rate pass-through, and macro-financial instability. Conversely, oil-price declines may weaken external balances and constrain public expenditure, thereby affecting industrial support and investor confidence. In the pharmaceutical sector, these transmission channels are especially important because firm performance often depends on cost-sensitive production structures, access to foreign currency, and stable regulatory procurement conditions. Studies examining the effect of oil price fluctuations on investment and financial performance support the idea that oil volatility is not neutral for corporate behavior and market valuation [7, 8]. Hence, modeling the impact of oil shocks on pharmaceutical stock return volatility is essential in any attempt to explain market behavior in the Tehran Stock Exchange.

Yet the effects of COVID-19 and oil-price volatility are unlikely to be constant across all states of the economy. One of the central arguments of recent macro-financial research is that shocks have state-dependent or regime-dependent effects. In other words, the same shock may produce limited responses under normal conditions but much stronger effects when the economy is under stress. This is precisely where the concept of financial stress becomes analytically valuable. Financial stress summarizes tensions across monetary, fiscal, and exchange-rate conditions and reflects the extent to which the financial system is vulnerable, constrained, or unstable. When financial stress rises, markets may become more sensitive to news, less liquid, and more nonlinear in their reactions. Under such circumstances, modest oil-price changes or pandemic-related uncertainty may trigger disproportionately large effects on stock return volatility. This makes the financial stress index not only an explanatory variable in its own right but also a potential threshold variable governing transitions between low-volatility and high-volatility regimes [1, 2].

The importance of nonlinear modeling is well established in environments characterized by uncertainty, structural breaks, and interaction effects. Linear models assume that marginal effects are constant regardless of the prevailing economic regime. However, this assumption is often unrealistic for financial markets, particularly in countries subject to repeated crises, commodity dependence, and policy volatility. Threshold and smooth-transition models offer a more realistic framework because they allow the magnitude of effects to change when an underlying transition variable crosses critical levels. In the present context, financial stress is a natural candidate for such a transition mechanism. When stress remains below a certain level, stock return volatility may respond moderately to oil shocks and pandemic effects. Once stress surpasses a threshold, however, the same variables may have stronger, faster, and more persistent impacts. This type of nonlinear structure is highly relevant for pharmaceutical companies listed on the Tehran Stock Exchange, where macroeconomic fragility, inflation, and crisis spillovers can intensify investor reactions [1, 3, 6].

The broader international literature on complexity, governance, technology, and energy transitions also helps frame the present study conceptually. Although these studies are not focused directly on pharmaceutical stock volatility, they provide strong evidence that economic systems behave differently depending on institutional quality, structural capacity, technological adaptation, and the interaction among macro-level variables. Research on economic complexity shows that institutional settings, integration, and structural transformation shape the way economies respond to shocks and pursue growth paths [9, 10]. Related work indicates that renewable energy adoption, green finance, energy efficiency, and technological innovation are embedded in broader structural conditions and often generate asymmetric or conditional effects rather than uniform ones across countries and sectors [11-19]. The common implication of this body of work is methodological as much as substantive: economic and financial outcomes are frequently shaped by interacting systems, thresholds, and contextual constraints.

A similar lesson emerges from studies of digitalization, technological systems, and intelligent optimization. Research has shown that digital-economy development can reshape deprivation and resource-allocation patterns, often through indirect and nonlinear channels [20]. Other studies on technical optimization and complex operational systems demonstrate that the behavior of modern economic and engineering processes cannot be fully understood without accounting for sensitivity, dynamic adjustment, and structured interdependence [19, 21]. Although the settings differ, these contributions reinforce a central idea relevant to financial-market research: when systems are complex, interconnected, and exposed to shocks, linear assumptions may obscure the true magnitude and direction of effects. This insight supports the use of advanced nonlinear econometric techniques such as Panel Smooth Transition Regression for studying stock return volatility under varying degrees of financial stress.

In the Iranian context, the need for such an approach is even greater. Pharmaceutical companies listed on the Tehran Stock Exchange operate in a setting shaped by inflation, regulated pricing, exchange-rate fluctuations, dependence on imported inputs, and sensitivity to public-health policy. During the COVID era, these firms faced both opportunities and risks. Demand expectations for pharmaceutical products may have risen, but supply constraints, uncertainty regarding international procurement, and volatility in macroeconomic conditions simultaneously increased. Evidence on the stock performance of pharmaceutical companies during the COVID period in Iran suggests that pandemic uncertainty had meaningful implications for market outcomes [2]. Likewise, research on managerial financial decisions during the COVID era underscores that the health crisis altered financing and decision-making environments for listed firms [4]. When these pandemic-related pressures are combined with oil-price instability and domestic financial stress, the case for a regime-sensitive volatility model becomes compelling.

Moreover, prior Iranian studies have typically examined the effects of COVID-19, oil-price shocks, or broad market crises separately, while fewer studies have integrated all three elements—pandemic conditions, oil volatility, and financial stress—within a unified threshold framework tailored to the pharmaceutical sector. This is a meaningful gap. The pharmaceutical industry differs from many other listed industries because its market valuation is influenced simultaneously by health demand, public policy, production costs, exchange-rate exposure, and investor perceptions of strategic importance. Therefore, the volatility of pharmaceutical stock returns may be especially sensitive to interactions among domestic stress conditions and external shocks. Existing research on the Tehran Stock Exchange points toward this complexity but leaves room for a more explicit nonlinear treatment that captures transitions between regimes and allows financial stress to alter the strength of oil and COVID effects [1-3, 5, 8].

From a policy and managerial perspective, this issue is also highly important. If stock return volatility in pharmaceutical firms intensifies disproportionately after financial stress crosses certain thresholds, then policymakers, regulators, and investors need early-warning indicators rather than average-effect estimates. Managers in listed pharmaceutical companies would benefit from understanding whether oil shocks and pandemic-type crises become materially more dangerous under stressed financial conditions. Regulators, in turn, need evidence on whether macro-financial stabilization can reduce sectoral volatility and preserve capital-market confidence during crises. Because pharmaceutical firms are strategically linked to national health resilience, instability in their stock performance can carry implications beyond investor wealth and extend to financing capacity, production continuity, and industrial confidence. A threshold-based approach can therefore generate more useful insights than standard linear models for both market participants and policymakers [1, 4, 7].

In sum, the literature indicates that stock market volatility in sensitive sectors is shaped by the interaction of macroeconomic shocks, crisis-related uncertainty, and structural financial conditions. The COVID-19 crisis introduced an unprecedented source of uncertainty into capital markets; oil-price fluctuations remained a major transmission channel in an oil-dependent economy; and financial stress likely amplified or moderated the impact of both. Previous empirical works provide evidence on these components individually and collectively, but they also suggest the need for a nonlinear, regime-dependent analysis centered on the pharmaceutical sector of the Tehran Stock Exchange [1-3, 5, 6, 8]. Therefore, the aim of this study is to investigate the threshold effects of financial stress on the relationship between oil price volatility and the COVID-19 crisis and stock return volatility in pharmaceutical companies listed on the Tehran Stock Exchange.

2. Methodology

The present study is applied in terms of objective and descriptive-analytical in nature, and it falls within the category of ex post facto research designs. Following prior studies such as Al-Rafay et al. (2022), Huynh et al. (2021), Sharif et al. (2020), Salisu et al. (2022), Zhang and Fu (2022), and Jahangir et al. (2022), this study investigates the effects of the COVID-19 crisis, financial stress, and oil price volatility on stock return volatility of pharmaceutical companies operating in the stock market using the Panel Smooth Transition Regression (PSTR) model.

The empirical model of the study is specified as follows:

$$R_t = \alpha_0 + \beta_1 FSI_t + \beta_2 COVID_t + \beta_3 OIL_t + \beta_4 INF_t + u_t$$

To examine the characteristics of the PSTR model with a logistic transition function based on Van Dijk (1999), it is assumed that the dependent variable $R$is also a function of its lagged values. Accordingly, under the assumption of a two-regime transition function, the following relationship is obtained:

$$R_t = (\theta_0 + \theta_1 R_{t-1} + \cdots + \theta_p R_{t-p}) + (\phi_0 + \phi_1 R_{t-1} + \cdots + \phi_p R_{t-p}) G(FSI_t, \gamma, c) + u_t$$

The transition function is defined as:

$$G(FSI_t, \gamma, c) = \frac{1}{1 + \exp\{-\gamma(FSI_t - c)\}}$$

The results of this model are referred to as a two-regime PSTR model, where the location parameter $c$represents the transition point between the two extreme regimes $G(FSI_t, \gamma, c) = 0$and $G(FSI_t, \gamma, c) = 1$, with the midpoint occurring at $G(FSI_t, \gamma, c) = 0.5$. The parameter γindicates the speed of transition between regimes, where larger values imply faster regime switching.

Dependent Variable:

R: Changes in returns resulting from fluctuations in the stock market index of pharmaceutical companies.

The standard deviation of the mean stock return during the fiscal year is calculated after computing stock price returns. Subsequently, the volatility of stock returns for the selected companies is estimated using ARCH and GARCH family models.

Calculation of Financial Stress Index (FSI):

The Financial Stress Index is calculated using Principal Component Analysis (PCA). The PCA method reduces the dimensionality of observations based on a composite index and groups similar observations. In this method, correlated variables in a multidimensional space are transformed into a set of uncorrelated components, each being a linear combination of the original variables. These uncorrelated components are referred to as principal components (PCs), derived from the eigenvectors of the covariance or correlation matrix of the original variables. One of the key advantages of this method in econometrics is the elimination of multicollinearity due to the large number of explanatory variables.

In the next step, a composite index derived from the volatility of the selected variables is estimated and introduced as an indicator of economic uncertainty. The financial stress index consists of three sectors: governmental, monetary, and exchange rate. After measuring financial stress in each sector, the overall financial stress index for the Iranian economy is computed by aggregating these sectoral indices. A critical issue in aggregation is the selection of an appropriate weighting scheme. Given the literature and the specific conditions of the Iranian economy, these sectors do not contribute equally to financial stress; therefore, a weighted approach is adopted.

In several studies, including Eston et al. (2018), Aboura and Van Roye (2017), and Semmler and Chen (2018), cyclical component regression has been applied. In this approach, the cyclical component of each variable used in constructing the composite index is regressed on the cyclical component of a reference variable (such as output growth). The resulting correlation coefficient is then used as the weighting criterion according to the following formula:

$$W_k = \frac{r_k^2}{\sum_{k=1}^{n} r_k^2}$$

Accordingly, in this study, to construct the overall financial stress index, after calculating sector-specific stress indices, the cyclical component of variables in each sector is regressed on the cyclical component of output growth. The obtained correlation coefficient is then used, based on Equation (3), to determine the weights of each sector in the aggregate financial stress index.

Table 1: Financial Stress Index Components

Variable Category	Variable	Definition	Operational Definition
Governmental Stress	GEXP	Government size	Ratio of total government expenditure to GDP
	TAXINC	Total tax revenues	Ratio of total tax revenue to GDP
	CU/M1	Currency to money ratio	Ratio of total currency in circulation to M1
Monetary Stress	SHD/LOD	Short-term to long-term deposits ratio	Ratio of short-term deposits to long-term deposits
	M1/M2	Money to liquidity ratio	Ratio of money supply to total liquidity
	Depo	Deposit ratio	Ratio of total deposits to GDP
	Pdebt	Non-governmental debt ratio	Ratio of non-governmental debt to GDP
	RInt	Real interest rate	Nominal interest rate minus inflation rate
Exchange Rate Stress	RER	Real exchange rate	$RER = \frac{ER \times P_{out}}{P_{in}}$

Finally, the financial stress index is computed using PCA and incorporated into the model.

$COVID$: Represents the global COVID-19 crisis, taking the value of 1 during pandemic months and 0 otherwise. Following the global outbreak of coronavirus disease, the pandemic was officially confirmed in Iran on February 19, 2020.

OIL: Represents oil price shocks for Iranian crude oil, which are estimated using the EGARCH model.

INF: Inflation rate, defined as the change in a price index, typically the Consumer Price Index (CPI).

3. Findings and Results

The empirical analysis began with the construction of the Financial Stress Index (FSI) using Principal Component Analysis (PCA). PCA was selected because the financial stress construct is multidimensional and is reflected in several highly related macro-financial indicators. In the present study, the composite index was extracted from nine indicators: government size (GEXP), total government tax revenues (TAXINC), currency-to-money ratio (CUM), the ratio of short-term to long-term deposits (SHDLOD), the money-to-liquidity ratio (M1M2), the deposit ratio (DEPO), the ratio of non-governmental debt (PDEBT), the real interest rate (RINT), and the real exchange rate (RER). The use of PCA reduced the dimensionality of the data, mitigated multicollinearity, and provided a parsimonious composite indicator suitable for subsequent nonlinear panel estimation.

In PCA, the observed variables can be represented as linear combinations of the principal components:

$$X_i = a_{i1}PC_1 + a_{i2}PC_2 + a_{i3}PC_3 + a_{i4}PC_4 + a_{i5}PC_5 + a_{i6}PC_6 + a_{i7}PC_7 + a_{i8}PC_8 + a_{i9}PC_9$$

Similarly, each principal component can be written as a weighted linear combination of the original variables:

$$PC_1 = w_1X_1 + w_2X_2 + w_3X_3 + w_4X_4 + w_5X_5 + w_6X_6 + w_7X_7 + w_8X_8 + w_9X_9$$

The correlation structure of the nine indicators is presented in Table 2. The matrix shows several moderate interrelationships among the variables, supporting the use of PCA for extracting a synthetic financial stress measure rather than entering all original indicators directly into the econometric model.

Table 2. Correlation Matrix of Financial Stress Indicators

Variable	GEXP	TAXINC	CUM	SHDLOD	M1M2	DEPO	PDEBT	RINT	RER
GEXP	1.000000								
TAXINC	0.165995	1.000000							
CUM	-0.103783	-0.358379	1.000000						
SHDLOD	-0.128613	-0.008877	0.187941	1.000000					
M1M2	0.032978	0.100707	0.131337	-0.228512	1.000000				
DEPO	0.609053	0.161638	-0.323739	-0.170545	-0.061763	1.000000			
PDEBT	0.525666	0.109060	0.025898	-0.031410	0.009685	0.414297	1.000000		
RINT	0.131295	0.223358	0.124128	0.476611	0.000612	0.114349	0.313530	1.000000	
RER	-0.122007	-0.310014	-0.085014	-0.443305	0.055429	0.146620	-0.060383	-0.518628	1.000000

Table 2 indicates that the financial stress indicators are not independent of one another. Particularly notable are the positive relationships between GEXP and DEPO, GEXP and PDEBT, and SHDLOD and RINT, as well as the negative association between RINT and RER. These patterns justify dimension reduction and confirm that a common latent stress factor can be extracted from the data.

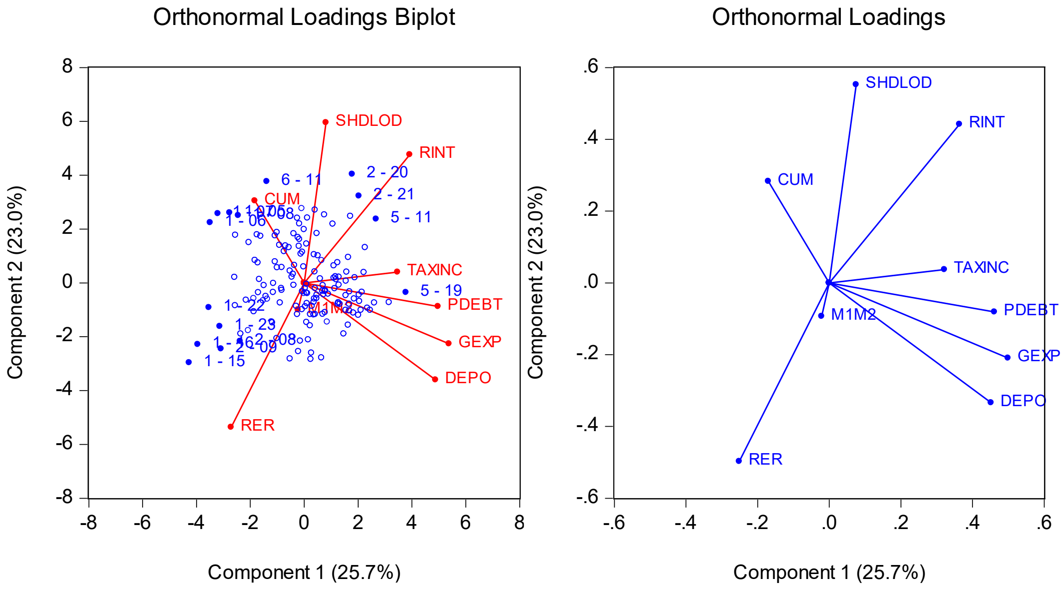

Figure 1. Transformation of Data into Principal Components

Figure 1 illustrates the geometric logic of PCA. The main direction of data dispersion does not lie exactly along any individual variable axis, but rather along the major axis of the ellipse formed by the data cloud. This direction corresponds to the first principal component, PC_1, which captures the largest possible proportion of total variation in the original variables. The second principal component, PC_2, lies along the minor axis of the ellipse, is orthogonal to PC_1, and captures the maximum remaining variance not explained by the first component.

The eigenvalues and factor loadings resulting from the PCA are reported in Table 3. The first principal component has the highest eigenvalue, 2.316320, and explains 25.74% of the total variation. The first four components have eigenvalues greater than one and jointly explain 75.79% of the total variance. Nonetheless, because the first component alone accounts for the largest share of common variation and serves as the clearest single-index representation of financial stress, it was selected as the composite FSI for the main model.

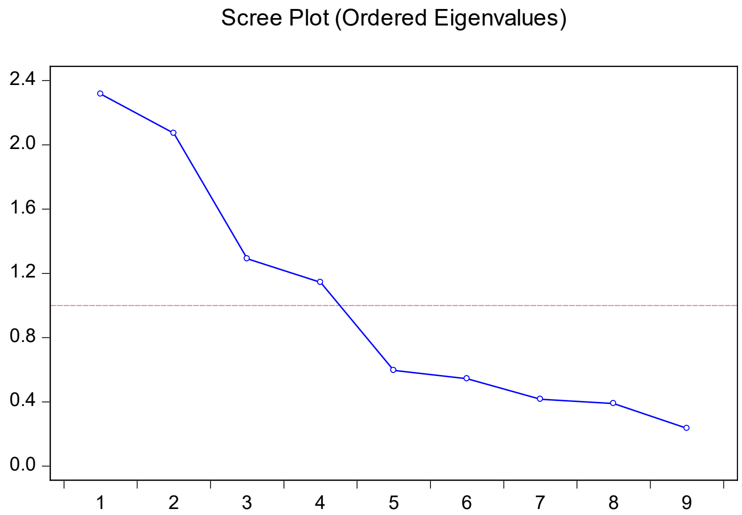

Figure 2. Scree Plot of Principal Components

Figure 2 presents the scree plot of the principal components. The pattern of eigenvalues shows a steep decline in the first few components, followed by a flattening trend. The break in the slope suggests that the first one to three components contain the most substantive information, while the remaining components contribute relatively little to explaining overall variation. This visual criterion is consistent with the eigenvalue and explained-variance criteria.

Table 3. PCA Results for the Composite Financial Stress Index

Panel A. Eigenvalues and Explained Variance

Component	Eigenvalue	Difference	Proportion	Cumulative Eigenvalue	Cumulative Proportion
1	2.316320	0.244827	0.2574	2.316320	0.2574
2	2.071493	0.781555	0.2302	4.387813	0.4875
3	1.289938	0.146412	0.1433	5.677751	0.6309
4	1.143526	0.547791	0.1271	6.821277	0.7579
5	0.595735	0.052060	0.0662	7.417012	0.8241
6	0.543675	0.127906	0.0604	7.960688	0.8845
7	0.415769	0.027118	0.0462	8.376457	0.9307
8	0.388651	0.153759	0.0432	8.765108	0.9739
9	0.234892	—	0.0261	9.000000	1.0000

Panel B. Eigenvectors (Factor Loadings)

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
GEXP	0.498997	-0.209736	0.225361	-0.013214	-0.400467	-0.400655	-0.003541	0.177866	0.550911
TAXINC	0.321701	0.036918	-0.570283	0.345787	-0.134822	0.300890	0.564911	0.144004	0.042207
CUM	-0.169882	0.283044	0.647471	0.162744	-0.275140	0.050451	0.580694	-0.126092	-0.118197
SHDLOD	0.075269	0.552262	0.002317	-0.266789	0.329713	-0.259983	0.140067	0.649376	-0.023430
M1M2	-0.021142	-0.093035	0.152450	0.848350	0.316871	-0.270020	-0.170742	0.194220	-0.088122
DEPO	0.452132	-0.334017	0.055934	-0.201237	0.294130	-0.355547	0.301367	-0.227171	-0.533882
PDEBT	0.461104	-0.081160	0.379751	-0.013977	0.021906	0.649800	-0.268456	0.307592	-0.216769
RINT	0.363735	0.441806	0.072586	0.069640	0.444137	0.110177	-0.047849	-0.546552	0.389847
RER	-0.251386	-0.497532	0.170049	-0.131740	0.502373	0.212369	0.360148	0.165463	0.434087

Based on the first principal component, the estimated financial stress index can be written as follows:

$$PC_1 = 0.49\,GEXP + 0.32\,TAXINC - 0.17\,CUM + 0.08\,SHDLOD$$
$$-0.02\,M1M2 + 0.45\,DEPO + 0.46\,PDEBT + 0.36\,RINT - 0.25\,RER$$

This expression shows that the first component loads positively on government size, tax revenues, deposits, non-governmental debt, and the real interest rate, while it loads negatively on the currency-to-money ratio, the money-to-liquidity ratio, and the real exchange rate. Therefore, increases in the former group of variables are associated with higher financial stress, whereas increases in the latter group reduce the composite score, all else equal.

The relative importance of the sub-indicators in the composite financial stress index is summarized in Table 4. Government size has the largest relative weight, followed by total tax revenues and the currency-to-money ratio. By contrast, the real exchange rate carries the smallest weight in the final composite indicator.

Table 4. Relative Importance of Variables in the Composite Financial Stress Index

Variable	Relative Importance (%)
Government size	25.74
Total government tax revenues	23.02
Currency-to-money ratio	14.33
Ratio of short-term to long-term deposits	12.71
Money-to-liquidity ratio	6.62
Deposit ratio	6.04
Non-governmental debt ratio	4.62
Real interest rate	4.32
Real exchange rate	2.61
Total	100.00

Table 4 confirms that the government sector contributes most strongly to the overall financial stress indicator. In substantive terms, this means that fiscal developments were the dominant source of common financial stress variation over the study period. After the composite FSI was generated through PCA, it was introduced as the transition variable in the PSTR model.

The next stage involved estimating oil price shocks. For this purpose, the EGARCH model proposed by Nelson (1991) was used because, unlike standard ARCH and GARCH models, it allows for asymmetric responses of volatility to positive and negative shocks. This is especially important in oil markets, where good and bad news often have uneven effects on uncertainty (Verbeek, 2005). The variance specification is:

$$\ln \sigma_t^2 = \alpha_0 + \alpha_1 \frac{| u_{t-1} |}{\sqrt{\sigma_{t-1}^2}} + \beta \ln \sigma_{t-1}^2 + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}}$$

with

$$\alpha_0 = \omega - \alpha \sqrt{\frac{2}{\pi}}, \alpha_1 = \alpha$$

If $\gamma = 0$, volatility responds symmetrically to positive and negative shocks. Otherwise, the response is asymmetric. The effect of positive shocks is $\alpha + \gamma$, whereas the effect of negative shocks is $\alpha - \gamma$.

Table 5. EGARCH Estimates for Oil Price Shock

Mean Equation	Coefficient	Std. Error	Variance Equation ($\ln \sigma_t^2$)	Coefficient	Std. Error
α_0	1.1819**	(0.4208)	α_0	5.0827***	(0.3473)
ρ_{t-1}	0.6435***	(0.0499)	$\ln \sigma_{t-1}^2$	0.1645***	(0.3473)
ρ_{t-2}	0.3944***	(0.0336)	$\frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}}$	2.1276***	(0.4938)
ρ_{t-3}	—	—	$\frac{\lvert u_{t-1}\rvert}{\sqrt{\sigma_{t-1}^2}}$	u_{t-1}	1.4403 (0.8498)

The positive value of the asymmetry parameter $\gamma = 2.1276$indicates that positive oil price shocks increase volatility more strongly than negative shocks of the same magnitude. Using the EGARCH decomposition, the estimated effect of a positive shock is $1.4403 + 2.1276 = 3.5679$, whereas the effect of a negative shock is $1.4403 - 2.1276 = -0.6873$. This confirms the existence of asymmetric oil-market volatility, with positive oil shocks generating substantially more uncertainty. This result is economically intuitive because positive oil price shocks are usually associated with concerns about supply disruption, thereby heightening uncertainty in global energy markets.

To measure stock return volatility for pharmaceutical firms, the return series was first modeled through an ARMA process following the Box-Jenkins methodology. The ARCH-LM test was then applied to verify the presence of conditional heteroskedasticity. Since the null of homoskedasticity was rejected, an EGARCH model was estimated to obtain the conditional variance series used later as the dependent variable in the PSTR model.

Table 6. Stock Return Mean and Volatility Estimation

Panel A. ARMA Model for Stock Returns

Variable	Coefficient	Std. Error	z-Statistic	p
AR(1)	1.014930	0.011936	85.03441	0.0000
MA(1)	-0.275550	0.037883	-7.273665	0.0000

Panel B. ARCH-LM Test

Test	Statistic	Value	p
F-statistic	$F(1,80)$	2.214044	0.0364
Obs*R-squared	$\chi^2(1)$	2.218810	0.0363

Panel C. EGARCH Model for Stock Return Volatility

Variable	Coefficient	Std. Error	z-Statistic	p
AR(1)	1.014930	0.011936	85.03441	0.0000
MA(1)	-0.275550	0.037883	-7.273665	0.0000
Variance Equation				
$\boldsymbol{C}(\mathbf{3})$	-1.460988	0.302531	-4.829211	0.0000
$\boldsymbol{C}(\mathbf{4})$	-0.557479	0.164041	-3.398404	0.0007
$\boldsymbol{C}(\mathbf{5})$	0.118678	0.138461	0.857123	0.3914
$\boldsymbol{C}(\mathbf{6})$	-0.842610	0.171831	-4.903725	0.0000

The ARMA estimates in Panel A show that stock returns depend significantly on both their first autoregressive lag and the first moving-average term. Panel B confirms the presence of conditional heteroskedasticity, since both ARCH-LM statistics are significant at the 5% level. Consequently, the use of a volatility model is warranted. In Panel C, the variance equation coefficients $C(3)$, $C(4)$, and $C(6)$are statistically significant, while the asymmetry term $C(5)$is not significant. Hence, stock return volatility in the pharmaceutical sector displays conditional heteroskedasticity and volatility persistence, but the asymmetric reaction of stock return volatility to shocks is not statistically strong in this particular series.

Before estimating the main nonlinear panel model, the stationarity properties of the variables and the existence of a long-run equilibrium relationship were examined. The Levin-Lin-Chu (LLC) panel unit root test was used for stationarity, and the Kao panel cointegration test was used to assess long-run association.

Table 7. Panel Unit Root and Cointegration Tests

Panel A. LLC Unit Root Test

Variable	LLC W-statistic	p	Order of Integration
COVID	-7.72984	0.0000	$I(0)$
FSI	-4.26833	0.0000	$I(0)$
INF	-5.65204	0.0000	$I(0)$
OIL	-5.26395	0.0000	$I(0)$
R	-7.94566	0.0000	$I(0)$

Panel B. Kao Panel Cointegration Test

Test	Statistic	p
ADF	-2.073416	0.0000

Table 7 shows that all variables are stationary at level. This finding eliminates the concern of spurious regression arising from nonstationary series. At the same time, the Kao ADF statistic is significant, indicating the existence of a stable long-run relationship among the variables included in the model.

The next step involved determining the appropriate model structure. First, the F-Limer test was used to determine whether pooled estimation or panel estimation was more appropriate. Second, the linearity of the model was examined using the BBC tests. Third, the remaining nonlinearity test was employed to determine whether one transition function was sufficient or whether additional transition functions were required. Following González et al. (2005) and Colletaz and Hurlin (2006), the results indicated that a single-transition PSTR specification was adequate.

Table 8. Model Identification, Linearity, and Remaining Nonlinearity Tests

Panel A. F-Limer Test for Model Selection

Test	Statistic	Degrees of Freedom	p	Selected Model
F-Limer	10.967198	(27, 304)	0.0015	Panel data
Chi-square	37.690239	27	0.0043	Panel data

Panel B. BBC Linearity Test

Test	F-Statistic	p
Wald	3.785	0.000
Fisher	2.638	0.001
LRT	2.957	0.012

Panel C. Remaining Nonlinearity Test

Hypothesis	LR	p	LMf	p	LMw	p
$\boldsymbol{H_0}: \boldsymbol{r} = \mathbf{1}, \boldsymbol{H_1}: \boldsymbol{r} = \mathbf{2}$ for $\boldsymbol{M} = \mathbf{1}$	1.432	0.654	1.471	0.630	1.352	0.743
$\boldsymbol{H_0}: \boldsymbol{r} = \mathbf{1}, \boldsymbol{H_1}: \boldsymbol{r} = \mathbf{2}$ for $\boldsymbol{M} = \mathbf{2}$	1.297	0.802	1.362	0.751	1.425	0.675

Panel A of Table 8 rejects the pooled-data specification in favor of panel-data estimation. Panel B rejects the null hypothesis of linearity under all three tests, confirming that the relationship between financial stress, oil shocks, the COVID-19 crisis, inflation, and stock return volatility is nonlinear. Panel C shows that the null hypothesis of a single transition function cannot be rejected under either the one-threshold or two-threshold alternative. Combined with the model-selection criteria reported in the estimation procedure, this result supports a PSTR model with one transition function and one threshold.

The final PSTR estimates are presented in Table 9. In this model, the transition variable is the financial stress index. The estimated threshold parameter is $c = 0.964102$, and the slope parameter is $\gamma = 6.675325$, both of which are statistically significant. The estimated transition function is therefore:

$$G(FSI_t; \gamma, c) = \frac{1}{1 + \exp\left[-6.675325(FSI_t - 0.964102)\right]}$$

This function implies a relatively sharp transition between the low-stress and high-stress regimes. When the financial stress index approaches and exceeds 0.964, the response of stock return volatility to the explanatory variables intensifies markedly.

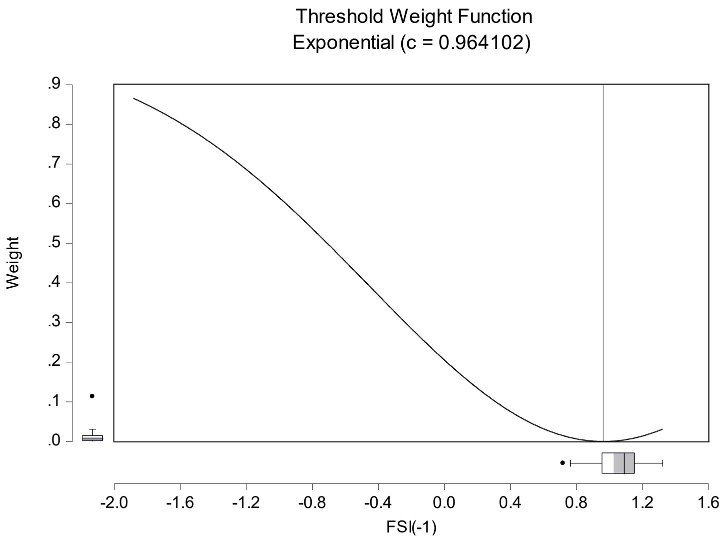

Figure 3. Relationship Between the Transition Function and the Financial Stress Transition Variable

Figure 3 depicts the logistic relationship between the transition variable and the transition function. As the financial stress index moves away from the threshold and enters the high-stress region, the transition function approaches one, meaning that the nonlinear component of the PSTR model becomes dominant. This confirms that the effect of macro-financial shocks on stock return volatility is regime-dependent rather than constant across all levels of financial stress.

Table 9. PSTR Estimates and Post-Estimation Diagnostic Tests

Panel A. Estimated PSTR Model

Variable	Coefficient	Std. Error	t-Statistic	p
Linear Part of the Model				
Constant	0.329059	0.136048	2.418698	0.0234
FSI	0.158886	0.075984	2.091051	0.0419
COVID	0.212527	0.090308	2.353357	0.0356
OIL	0.096233	0.026454	3.637702	0.0003
INF	0.197885	0.085146	2.324058	0.0201
Nonlinear Part of the Model				
Constant	0.016839	0.006021	2.796881	0.0049
FSI	0.996017	0.222131	4.483915	0.0000
COVID	0.582868	0.239013	2.438640	0.0149
OIL	0.120704	0.060604	1.991677	0.0487
INF	0.496421	0.175702	2.825358	0.0069
Threshold parameter $\boldsymbol{c}$	0.964102	0.158623	6.077495	0.0000
Slope parameter $\boldsymbol{\gamma}$	6.675325	2.934622	2.274678	0.0284

$Adjusted\ R^2 = 0.88$

Panel B. Residual Diagnostics

Test	Statistic	p	Additional Statistic
Autocorrelation test	$F = 1.235$	0.690	Durbin-Watson = 2.036
Breusch-Pagan-Godfrey heteroskedasticity test	$F = 1.298$	0.556	LM = 1.327

Panel C. Parameter Constancy Across Regimes

Null Hypothesis	F-Statistic	p
$\boldsymbol{b_1 = b_2 = b_3 = b_4 = 0}$	0.745	0.754
$\boldsymbol{b_1 = b_2 = b_3 = 0}$	0.798	0.712
$\boldsymbol{b_1 = b_2 = 0}$	0.821	0.695
$\boldsymbol{b_1 = 0}$	0.836	0.674

The linear component of the PSTR model shows that financial stress, the COVID-19 crisis, oil price shocks, and inflation all exert positive and statistically significant effects on stock return volatility in the pharmaceutical sector. However, the nonlinear component indicates that these effects become considerably stronger once the financial stress index crosses the estimated threshold. In the high-stress regime, the approximate total coefficients become 1.154903for FSI, 0.795395for COVID, 0.216937for OIL, and 0.694306for INF, obtained by adding the linear and nonlinear coefficients. This means that stock return volatility reacts much more sharply to macro-financial disturbances under conditions of elevated financial stress.

Panel B of Table 9 indicates that the residuals do not suffer from autocorrelation or heteroskedasticity, confirming that the estimated model satisfies key classical diagnostic requirements. Panel C further shows that the smooth-transition parameters remain stable across regimes, which supports the adequacy and robustness of the estimated nonlinear specification.

Overall, the findings demonstrate that stock return volatility in listed pharmaceutical firms is not only influenced by oil price shocks, the COVID-19 crisis, inflation, and domestic financial stress, but that the magnitude of these effects changes nonlinearly across financial stress regimes. The estimated threshold of 0.964 for the financial stress index marks the point at which the behavior of stock return volatility shifts from a relatively moderate regime to a substantially more sensitive high-stress regime.

4. Discussion and Conclusion

The findings of the present study provide strong evidence that stock return volatility in pharmaceutical companies listed on the Tehran Stock Exchange is shaped by a combination of domestic financial stress, the COVID-19 crisis, oil price shocks, and inflation, and that these effects are fundamentally nonlinear. The estimated Panel Smooth Transition Regression model showed that all core explanatory variables exerted positive and statistically significant effects on stock return volatility in the linear regime, while the nonlinear regime amplified these effects substantially once the financial stress index crossed the estimated threshold. More specifically, financial stress had a positive and significant effect on return volatility in both the linear and nonlinear parts of the model, and its coefficient increased sharply in the high-stress regime. COVID-19 also had a significant positive effect on stock return volatility, indicating that the pandemic period heightened uncertainty in the market for pharmaceutical firms. Oil price shocks were similarly found to increase volatility, and inflation also exerted a significant positive effect. The estimated threshold parameter and slope coefficient confirmed that the transition from the low-stress regime to the high-stress regime was meaningful and relatively sharp, suggesting that stock return volatility becomes much more sensitive to macro-financial shocks when domestic financial conditions deteriorate. In addition, the diagnostic tests supported the adequacy of the estimated model, as the variables were stationary, cointegrated, free from residual autocorrelation and heteroskedasticity, and the nonlinear specification with one transition function was shown to be appropriate.

The first major result of the study concerns the direct and nonlinear effect of financial stress on stock return volatility. The positive coefficient of the financial stress index in both regimes indicates that rising stress in the domestic financial environment increases the instability of pharmaceutical stock returns. More importantly, the much larger coefficient in the nonlinear regime suggests that the effect of financial stress is not constant; rather, once financial stress surpasses a critical threshold, investor reactions intensify and the market becomes substantially more fragile. This finding is consistent with studies showing that stock performance in the Tehran Stock Exchange is highly sensitive to crisis conditions, external shocks, and macro-financial instability [1, 3]. It also aligns with the study of uncertainty related to COVID-19 and pharmaceutical stock performance, which showed that uncertainty indicators can meaningfully shape the valuation and fluctuation of pharmaceutical firms in Iran [2]. The present result adds to this literature by showing that financial stress is not only an explanatory condition but also a transition mechanism that changes the intensity of the effects of other shocks. This interpretation is also compatible with broader research emphasizing the importance of structural conditions, institutional arrangements, and systemic complexity in shaping economic outcomes [9, 10]. In this sense, the Iranian pharmaceutical stock market appears to behave as a regime-dependent system in which the same shock may have a modest effect under stable conditions but a much stronger effect under financial strain.

The second important finding relates to the role of the COVID-19 crisis. The positive and significant coefficient for the pandemic dummy variable indicates that the COVID-19 period increased stock return volatility in pharmaceutical companies. At first glance, one might expect pharmaceutical firms to benefit from a health crisis because of increased demand for medical products and strategic attention from policymakers and investors. However, the results suggest that in the Iranian market the uncertainty, disruptions, and speculative pressures associated with the pandemic outweighed any stabilizing demand-side effects. This result is fully consistent with earlier research showing that the COVID-19 crisis produced marked changes in stock return indices and market performance in Iran and elsewhere [3, 5, 6]. It also corresponds with evidence that listed-company managers altered their financial decisions during the COVID era, reflecting heightened uncertainty and changing operational constraints [4]. The consistency of the present result with prior findings implies that even firms located in a health-related sector were not insulated from the destabilizing financial effects of the pandemic. Rather, the pharmaceutical sector appears to have been exposed to multiple uncertainty channels simultaneously, including supply disruptions, exchange-rate pressures, regulatory unpredictability, and abrupt shifts in investor expectations [1, 2].

A particularly important contribution of the present study is that it shows the effect of COVID-19 was even stronger under high financial stress. The nonlinear coefficient of the COVID variable demonstrates that the pandemic did not affect stock return volatility in a uniform way across all conditions. Instead, when the economy entered a higher-stress regime, the volatility-enhancing effect of COVID-19 became stronger. This finding has a strong theoretical basis because crises tend to interact rather than operate independently. A health crisis imposed on a financially stressed economy can deepen information asymmetry, reduce investor confidence, worsen liquidity conditions, and magnify emotional trading. Such an interaction helps explain why the response of pharmaceutical stock returns was not merely additive but state-dependent. This interpretation is in line with evidence from stock-market crisis studies showing that the market response to COVID-19 varied across countries and sectors depending on institutional and structural conditions [5, 6]. It also resonates with wider research demonstrating that economic systems respond differently to shocks depending on governance quality, structural transformation, and the prevailing state of the economy [9, 10]. Thus, the present study extends the COVID-finance literature by showing that the volatility effect of the pandemic in pharmaceutical stocks is conditioned by domestic financial stress.

The third major result concerns the positive and significant impact of oil price shocks on stock return volatility. This finding is economically plausible in the context of Iran because oil-price movements affect not only energy markets but also fiscal expectations, liquidity conditions, exchange rates, inflation, and the broader macroeconomic environment. Pharmaceutical firms, although not producers of oil, are still affected by oil-price fluctuations through production costs, imported intermediate inputs, transportation expenses, and shifts in government fiscal capacity. The present finding is consistent with studies reporting that oil price fluctuations significantly affect stock returns, exchange rates, and corporate investment behavior [7, 8]. It also aligns with modeling efforts emphasizing the importance of oil price shocks in explaining stock price dynamics on the Tehran Stock Exchange [1]. The additional EGARCH results in the present study further showed that positive oil price shocks generate greater volatility than negative shocks, confirming the existence of asymmetry in oil-market uncertainty. This asymmetry is consistent with the argument that positive oil-price shocks are often associated with supply concerns and heightened uncertainty, whereas negative shocks are less capable of fully reversing prior volatility effects [7, 8]. Consequently, the oil channel appears to be one of the key transmission mechanisms through which macroeconomic instability spills over into pharmaceutical stock volatility.

The nonlinear part of the model also indicates that oil shocks become more influential when financial stress rises above the threshold. This is a meaningful result because it suggests that oil-price volatility is not equally disruptive in all macro-financial environments. Under relatively stable financial conditions, firms and investors may absorb oil-related uncertainty more effectively. Under stressed conditions, however, oil shocks can trigger stronger market reactions because they are interpreted as signals of worsening inflation, exchange-rate instability, fiscal imbalance, or broader uncertainty. This finding aligns with the broader literature on complex and nonlinear economic systems, which emphasizes that the impact of a given shock depends on the state of the system receiving it [13-15]. Although these studies focus mainly on energy transitions, economic complexity, and structural transformation, their central implication is relevant here: the consequences of energy-related changes are conditional upon broader institutional and macroeconomic settings. The present study transfers this logic to a financial-market setting and shows that pharmaceutical stock volatility responds to oil shocks in a state-contingent manner.

Another important finding is the positive and significant effect of inflation on stock return volatility. Inflation is a particularly important macroeconomic variable in emerging and structurally imbalanced economies because it influences purchasing power, interest-rate expectations, production costs, financing conditions, and investor discount rates. In the pharmaceutical sector, inflation may be especially destabilizing due to cost pressures on imported inputs, uncertainty regarding regulated pricing, and tension between nominal revenue growth and real profitability. The result that inflation increases stock return volatility is consistent with the broader macro-financial logic of inflationary economies and also complements the findings of studies linking stock-market behavior in Iran to macroeconomic instability and exchange-rate-related uncertainty [1, 8]. The stronger inflation effect in the nonlinear regime further indicates that price instability becomes particularly damaging when combined with elevated financial stress. This suggests that inflation is not merely a background macroeconomic condition but a volatility amplifier under stressed regimes.

The adequacy of the nonlinear specification constitutes another substantive result. The rejection of linearity by the BBC tests, together with the confirmation that one transition function is sufficient, indicates that the relationship among financial stress, COVID-19, oil shocks, inflation, and stock return volatility cannot be properly captured by a conventional linear panel model. This result is methodologically important because it supports the use of Panel Smooth Transition Regression as a more realistic framework for analyzing financial-market behavior in crisis-prone settings. The significance of the threshold parameter and slope parameter indicates that regime shifts are not arbitrary but are statistically meaningful features of the data-generating process. This conclusion is in harmony with studies in other areas of economics and sustainability that have emphasized sensitivity, nonlinear adjustment, and the importance of contextual thresholds in determining observed outcomes [12, 16, 17, 19]. Even though those studies examine green innovation, renewable-energy systems, and techno-economic optimization rather than stock volatility, they collectively support the broader proposition that complex systems rarely respond to external pressures in a strictly linear fashion.

From a conceptual standpoint, the results can also be interpreted through the lens of systemic complexity. The literature on economic complexity, digital transformation, and structural capability suggests that outcomes emerge from the interaction of multiple subsystems rather than isolated variables [9, 11, 20]. In a similar way, the present findings show that stock return volatility in pharmaceutical firms is not simply the direct result of one isolated factor such as COVID-19 or oil prices. Instead, it reflects the interaction among global shocks, domestic financial conditions, inflationary pressures, and regime-switching behavior in investor responses. This means that volatility in the pharmaceutical stock market should be viewed as a systemic phenomenon arising from layered uncertainty rather than a narrow market anomaly. The finding that financial stress is the transition variable reinforces this systemic reading: when domestic financial conditions worsen, the system becomes more reactive, and all major shocks exert stronger effects.

Overall, the discussion of results suggests that the pharmaceutical sector in the Tehran Stock Exchange occupies a particularly sensitive position within the Iranian economy. It is simultaneously exposed to crisis-induced demand expectations, macroeconomic instability, imported-input dependence, and sector-specific policy dynamics. The study therefore contributes to the literature by integrating COVID-19, oil price shocks, inflation, and financial stress within a single nonlinear framework and by demonstrating that financial stress governs the transition between low-impact and high-impact regimes. This result is broadly compatible with previous studies on Iranian stock-market behavior during crises [1-3, 5], with evidence on oil-related financial effects [7, 8], and with wider research on structural complexity, technological transformation, and conditional responses in economic systems [10, 13, 18, 21]. In this respect, the results are both empirically grounded and theoretically coherent.

One limitation of the present study is that it focuses only on pharmaceutical companies listed on the Tehran Stock Exchange, which may limit the generalizability of the findings to other industries with different cost structures, regulatory environments, and exposure to macroeconomic shocks. Another limitation is that the COVID-19 crisis was represented through a dummy variable, which captures the timing of the pandemic but may not fully reflect the intensity, duration, or changing phases of pandemic-related uncertainty. In addition, although the financial stress index was carefully constructed from several macro-financial indicators, other potentially relevant dimensions of uncertainty, such as sanctions intensity, firm-level governance quality, and international trade restrictions, were not explicitly incorporated into the model. Finally, while the PSTR framework is well suited to capturing smooth nonlinear transitions, it may still abstract from abrupt structural breaks or multiple overlapping crises that characterize the Iranian economic environment.

Future research can extend the present study in several directions. First, similar threshold-based models can be estimated for other strategic industries, such as petrochemicals, food, banking, and medical equipment, in order to compare whether financial stress operates in the same way across sectors. Second, future studies may replace the binary COVID measure with more refined indicators of pandemic uncertainty, health-system pressure, or epidemic intensity. Third, firm-level variables such as leverage, ownership structure, export orientation, research and development intensity, and dependence on imported inputs can be incorporated into nonlinear panel models to determine whether firm heterogeneity moderates the threshold effects identified here. Fourth, future research may compare alternative nonlinear frameworks, such as Markov-switching models, threshold VAR models, or quantile-based panel approaches, to assess whether the results remain robust across methodologies. Finally, cross-country comparative studies involving similar pharmaceutical sectors in other emerging markets would help clarify whether the observed regime-dependent effects are specific to Iran or reflect a broader emerging-market pattern.

From a practical perspective, the results imply that policymakers, investors, and corporate managers should not evaluate the risks facing pharmaceutical stocks on the basis of average effects alone. The evidence suggests that once financial stress rises beyond a critical level, the stock market becomes much more sensitive to oil shocks, inflation, and crisis conditions. Therefore, regulators should monitor domestic financial stress as an early-warning indicator and adopt stabilizing measures before the market enters a high-sensitivity regime. Investors may use threshold-based risk assessment to improve portfolio management and avoid underestimating volatility in periods of macro-financial tension. Managers in pharmaceutical firms should also strengthen financial resilience, improve hedging against macroeconomic shocks, and enhance scenario planning during periods of rising financial stress. More broadly, efforts to reduce inflationary instability, improve financial-system confidence, and support stable access to production inputs may help contain excess volatility and improve the resilience of pharmaceutical firms in the capital market.

Authors' Contributions

Authors equally contributed to this article.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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References

[1] S. Raeisi, "Presenting a Stock Price Index Model for Companies Listed on the Tehran Stock Exchange with Emphasis on the Global Financial Crisis, COVID-19, Exchange Rate Fluctuations, and Oil Price Shocks," 2025.
[2] R. Amani and A. Assari Arani, "Estimation of the COVID-19 Disease Uncertainty Index and Its Effect on the Stock Performance of Pharmaceutical Companies Listed on the Tehran Stock Exchange," 2025.
[3] S. H. Vaghfi, L. Darvishi, and Z. Nourbakhsh Hosseini, "The Comparative Impact of the Global Financial Crisis and the COVID Crisis on Iran's Capital Market," 2022.
[4] F. Kazemi Bareh Bichast and Z. Alborzi Sibak, "Exploring the Financial Decisions of Listed Company Managers During the COVID Era: A Test from the Experience of the Health Crisis," Tehran, 2024.
[5] S. Sahneh, P. Shaban Khamseh, G. Fattah Dehno, E. Sajedi Badashian, H. Banj Shafiei, and S. Ayazi, "The Impact of COVID-19 on the Stock Return Index," Aliabad, 2024.
[6] N. Bagheri Zamani, H. Shajari, M. Sameti, and Z. Zamani, "بررسی اثرات سرریز ناشی از پاندمی ویروس کرونا بر بازار سهام منتخبی از کشورها," Damghan, 2023.
[7] S. Asta, B. Parsafard, and H. Sheikhi, "The Effect of Oil Price Fluctuations and Stock Returns on the Level of Corporate Investment," 2025.
[8] M. E. Raei Ezzabadi, M. Masoudi, and J. Shirvani, "The Effect of Oil Price Fluctuations on Returns and Exchange Rate with the Role of Economic Policy Uncertainty," Tehran, 2024.
[9] C. P. Nguyen, C. Schinckus, and T. D. Su, "Determinants of economic complexity: a global evidence of economic integration, institutions, and internet usage," *Journal of the Knowledge Economy*, vol. 14, no. 4, pp. 4195-4215, 2023, doi: 10.1007/s13132-022-01053-3.
[10] C. Agu, J. E. Ogbuabor, and B. U. Onah, "How are economic governance institutions moderating the effect of economic complexity on trade, FDI inflow, environmental degradation, and economic growth in Africa?," *Journal of the Knowledge Economy*, pp. 1-32, 2024, doi: 10.1007/s13132-024-02284-2.
[11] C. Li and M. Umair, "Does green finance development goals affect renewable energy in China," *Renewable Energy*, vol. 203, pp. 898-905, 2023, doi: 10.1016/j.renene.2022.12.066.
[12] A. Song, Z. Rasool, R. Nazar, and M. K. Anser, "Towards a greener future: how green technology innovation and energy efficiency are transforming sustainability," *Energy*, vol. 290, p. 129891, 2024, doi: 10.1016/j.energy.2023.129891.
[13] V. M. Taghvaee, B. Saboori, S. Soretz, C. Magazzino, and M. Tatar, "Renewable energy, energy efficiency, and economic complexity in the Middle East and North Africa: a panel data analysis," *Energy*, vol. 311, p. 133300, 2024, doi: 10.1016/j.energy.2024.133300.
[14] A. C. Nuta, "The significance of economic complexity and renewable energy for decarbonization in Eastern European countries," *Energies*, vol. 17, no. 21, p. 5271, 2024, doi: 10.3390/en17215271.

[15] E. Saadaoui, E. Omri, and N. Chtourou, "The transition to renewable energies in Tunisia: the asymmetric impacts of technological innovation, government stability, and democracy," *Energy,* vol. 293, p. 130686, 2024, doi: 10.1016/j.energy.2024.130686.

[16] B. Dogan, E. Nketiah, S. Ghosh, and A. A. Nassani, "The impact of green technology on renewable energy innovation: fresh pieces of evidence under the role of research and development and digital economy," *Renewable and Sustainable Energy Reviews,* vol. 210, p. 115193, 2025, doi: 10.1016/j.rser.2024.115193.

[17] X. Liao, S. Bresciani, C. Troise, W. A. A. Bukhari, and A. A. A. Bukhari, "How solar, wind, and biomass energy create sustainable pathways towards green economic growth? Insights from the top five global renewable energy economies," *Sustainable Development*, 2025, doi: 10.1002/sd.3345.

[18] B. Gajdzik, R. Nagaj, R. Wolniak, D. Balaga, B. Zuromskaite, and W. W. Grebski, "Renewable energy share in European industry: analysis and extrapolation of trends in EU countries," *Energies,* vol. 17, no. 11, p. 2476, 2024, doi: 10.3390/en17112476.

[19] P. H. Kumar *et al.*, "Techno-economic optimization and sensitivity analysis of off-grid hybrid renewable energy systems: a case study for sustainable energy solutions in rural India," *Results in Engineering,* vol. 25, p. 103674, 2025, doi: 10.1016/j.rineng.2024.103674.

[20] C. Xinxin, M. Umair, S. u. Rahman, and Y. Alraey, "The potential impact of digital economy on energy poverty in the context of Chinese provinces," *Heliyon,* vol. 10, no. 9, p. e30140, 2024, doi: 10.1016/j.heliyon.2024.e30140.

[21] C. Jing *et al.*, "Study on sustained-release kinetics of intelligent tracer for water search in horizontal wells," *Geoenergy Science and Engineering,* vol. 227, p. 211861, 2023, doi: 10.1016/j.geoen.2023.211861.