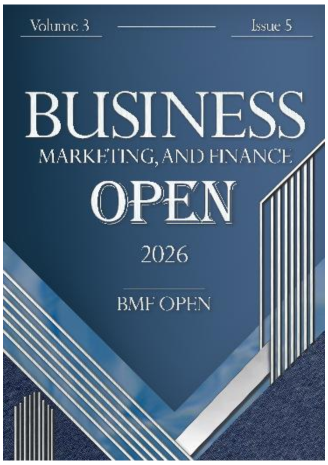
Threshold Effect of Financial Stress in the Relationship Between Global Crude Oil Price Volatility Spillovers and the Base Metals Market of Listed Companies



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Abstract: This study investigates the spillover effects of global crude oil price volatility on the base metals market of companies listed in Iran during the 2013–2024 period. The primary objective of the study is to identify the role of oil price fluctuations and financial stress in the base metals market and to analyze the effects of firms' production and structural variables. To analyze the data, the Panel Smooth Transition Regression (PSTR) model was employed, which is capable of examining both linear and nonlinear effects of independent variables as well as the role of the threshold variable. The independent variables include oil price volatility, labor force, gross fixed capital formation, and firm size, while financial stress acts as the threshold variable in the model. The findings indicate that oil price volatility and financial stress exert negative effects, whereas labor force, gross fixed capital formation, and firm size exert positive effects on base metals prices. The effects of the variables in the linear component of the model are relatively stable and direct; however, once the financial stress index exceeds the threshold level, nonlinear effects emerge and the intensity of the variables' impacts either increases or adjusts. Specifically, an increase in financial stress intensifies the negative effect of oil price volatility and weakens the positive effects of labor force and gross fixed capital formation, while the positive effect of firm size is strengthened under high-stress conditions. Based on the findings, it is recommended that policies related to energy risk hedging, development of production infrastructure, enhancement of labor force skills, strengthening of the banking system, and support for long-term corporate investment be prioritized. Implementation of these policies can mitigate the adverse effects of oil price volatility and financial stress on the base metals market and enhance the stability of product prices.

Keywords: Oil Price Volatility, Financial Stress, Base Metals Market, Panel Smooth Transition Regression Model (PSTR)

1. Introduction

The global economy has experienced substantial transformations over recent decades due to fluctuations in commodity markets, increasing geopolitical uncertainty, and structural changes in financial systems. Among strategic commodities, crude oil and base metals occupy a critical position because of their extensive role in industrial production, energy supply chains, infrastructure development, and international trade. Oil price volatility not only affects energy-intensive industries directly but also transmits shocks to financial markets and commodity markets through interconnected channels of production costs, investment behavior, and macroeconomic expectations. In resource-dependent economies, especially emerging economies with fragile institutional structures and underdeveloped financial systems, the spillover effects of oil price fluctuations can become more severe and nonlinear. Consequently, understanding the transmission mechanism between oil market volatility and base metals markets has become one of the major concerns in financial economics and industrial policy research [1-3]. Studies on commodity interconnectedness demonstrate that energy markets and metal markets exhibit significant co-movements due to common macroeconomic drivers, financialization processes, and investor sentiment. Increasing globalization and the integration of commodity markets have intensified the speed and magnitude of volatility transmission between oil and industrial metals. In this regard, empirical evidence suggests that shocks originating in oil markets may influence the returns, volatility, and pricing structure of industrial metals such as copper, aluminum, zinc, nickel, and lead through channels related to production costs, inflationary expectations, and global industrial demand [4-7]. Furthermore, the dynamic relationship between commodity markets is often asymmetric and regime-dependent, implying that the intensity of spillovers may vary across periods of economic stability and financial stress. This nonlinear behavior has motivated researchers to employ advanced econometric techniques capable of capturing threshold effects and structural transitions in commodity markets [8-10].

The importance of oil price volatility for resource-rich economies extends beyond commodity markets and directly affects economic growth, industrial productivity, and financial development. In many developing economies, oil revenues constitute a substantial share of government income and foreign exchange earnings, making these economies highly vulnerable to external shocks. Volatility in oil prices can generate instability in fiscal balances, exchange rates, inflation, and investment flows, ultimately influencing industrial sectors that depend heavily on imported machinery, intermediate inputs, and energy resources. In countries with weak institutional quality and inefficient financial systems, these effects may become more pronounced because governments and firms possess limited capacities to absorb external shocks effectively [11-13]. The literature on the resource curse and institutional economics indicates that the impact of natural resources on economic performance depends significantly on institutional quality, governance efficiency, and financial market stability. Economies characterized by stronger institutions and diversified industrial structures are generally more resilient to commodity price shocks and better able to transform resource wealth into sustainable economic development [14-16]. In contrast, economies with institutional weaknesses often experience greater volatility transmission, financial instability, and inefficient allocation of resource revenues [17-19].

The Iranian economy represents a significant case for examining the relationship between oil price volatility and the base metals market because of its high dependence on energy revenues, industrial concentration in energy-intensive sectors, and exposure to financial and geopolitical risks. Base metals industries in Iran, including copper, aluminum, steel, and zinc production, rely heavily on energy consumption, imported technology, and access to financial resources. Therefore, fluctuations in global oil prices can directly influence production costs, export competitiveness, and investment decisions in these industries. Previous studies on Iran have demonstrated that oil price shocks significantly affect industrial stock returns, macroeconomic stability, and sectoral performance [20, 21]. However, despite the strategic importance of base metals industries, limited attention has been devoted to examining how financial stress alters the relationship between oil price volatility spillovers and base metals markets in Iran. Most previous studies have focused either on macroeconomic consequences of oil dependency or on linear relationships among commodity prices, without adequately considering nonlinear dynamics and threshold effects arising from financial instability [11, 12].

Recent developments in commodity market analysis emphasize the importance of volatility spillover frameworks for understanding the interconnectedness of energy and metals markets. Volatility spillovers occur when uncertainty or shocks in one market transmit to another market, thereby affecting price stability, investment behavior, and market expectations. The increasing financialization of commodity markets has strengthened these transmission mechanisms by integrating commodities into global investment portfolios and speculative trading activities. Empirical findings reveal that volatility spillovers between oil and metal markets are time-varying and become stronger during periods of economic crises, geopolitical tensions, and financial uncertainty [3, 22, 23]. Studies have also shown that geopolitical risk and economic policy uncertainty significantly intensify volatility transmission in industrial and precious metals markets [2, 24]. These findings imply that financial stress can play a crucial role in shaping the magnitude and direction of volatility spillovers between oil and metals markets. Financial stress affects firms' access to capital, investor confidence, banking sector liquidity, and market expectations, thereby amplifying the sensitivity of commodity markets to external shocks [13, 25].

Another important dimension of the literature relates to economic complexity and productive capacities in resource-rich economies. Economic complexity refers to the diversity and sophistication of productive structures and export capabilities within an economy. Economies with higher levels of economic complexity generally possess stronger industrial resilience, greater innovation capacities, and improved adaptability to external shocks. The relationship between natural resource abundance and economic complexity has attracted growing scholarly attention because excessive dependence on natural resources may hinder industrial diversification and technological progress [26-28]. However, recent studies argue that natural resources can become a source of industrial upgrading and export diversification when supported by efficient institutions and productive investment strategies [29, 30]. Economic complexity also mediates the relationship between institutional quality and industrial competitiveness, implying that countries with more sophisticated productive structures may exhibit lower vulnerability to commodity price volatility [31-33]. In the context of base metals industries, productive capacity, labor quality, and capital accumulation can moderate the negative effects of oil price volatility by enhancing firms' operational flexibility and competitiveness.

Institutional quality constitutes another critical factor affecting the transmission of oil price shocks and financial stress into industrial markets. Strong institutional frameworks improve regulatory effectiveness, financial transparency, and policy coordination, thereby reducing market uncertainty and facilitating investment flows. In contrast, institutional weaknesses may intensify financial stress and increase the vulnerability of commodity-dependent industries to external shocks [16, 21, 34]. Empirical studies indicate that institutional quality mediates the relationship between natural resources and economic performance by influencing resource allocation efficiency, governance stability, and industrial diversification [18, 31, 35]. Furthermore, financial development and institutional quality jointly determine the capacity of firms and governments to manage commodity-related risks [12]. In economies characterized by institutional fragility, increases in financial stress can generate nonlinear reactions in industrial markets because firms face tighter financing constraints, reduced investor confidence, and heightened uncertainty. Consequently, the interaction between oil price volatility and financial stress may exhibit threshold effects that cannot be adequately captured through conventional linear econometric models.

The methodological evolution of commodity market research has increasingly emphasized nonlinear and regime-switching models to capture asymmetric market behavior. Traditional linear models often fail to identify structural breaks, threshold effects, and nonlinear transmission mechanisms associated with financial crises and market instability. Therefore, econometric approaches such as Smooth Transition Regression (STR), Markov-switching models, and nonlinear panel methods have become widely used in analyzing commodity market dynamics [5, 8, 9]. The Panel Smooth Transition Regression (PSTR) model is particularly suitable for examining nonlinear relationships because it allows coefficients to change gradually across different regimes depending on the value of a transition variable. In the context of the present study, financial stress can serve as an effective transition variable because its increase may alter the magnitude and direction of the relationship between oil price volatility and base metals prices. Such nonlinear mechanisms are especially relevant in emerging economies where financial instability often interacts with commodity market shocks and institutional weaknesses.

Moreover, the relationship between natural resources, financial stress, and industrial performance has become increasingly complex due to globalization, sanctions, geopolitical conflicts, and climate-related uncertainties. Resource-rich economies frequently experience amplified volatility because global commodity markets are highly sensitive to political and economic shocks [1, 2]. In addition, increasing uncertainty in global energy markets influences investor expectations and speculative behavior, which further strengthens volatility transmission between oil and metals markets [6, 7]. Under such conditions, firms operating in base metals industries may encounter severe fluctuations in production costs, export revenues, and financing conditions. Therefore, identifying the threshold level at which financial stress significantly changes market behavior is highly important for policymakers and industrial managers. Such knowledge can contribute to the design of effective risk management strategies, stabilization policies, and industrial support mechanisms.

Despite the extensive literature on oil price shocks, volatility spillovers, and institutional quality, several important research gaps remain unresolved. First, previous studies have rarely focused on the nonlinear interaction between financial stress and oil price volatility spillovers in the context of base metals industries. Second, many existing studies concentrate on developed economies or aggregate commodity indices, while emerging resource-dependent economies such as Iran remain underexplored. Third, most studies have examined volatility transmission using symmetric models that may overlook threshold effects and regime-dependent dynamics. Fourth, the interaction among labor force, capital accumulation, firm size, and financial stress in shaping base metals market behavior has not been adequately investigated within a unified nonlinear framework. Addressing these gaps is important because understanding the nonlinear effects of financial stress can improve policy responses aimed at stabilizing industrial markets and enhancing economic resilience.

Given the strategic importance of base metals industries for industrial production, export revenues, and economic development in Iran, examining the threshold effect of financial stress in the relationship between global crude oil price volatility spillovers and the base metals market can provide valuable insights for policymakers, investors, and industrial managers. Therefore, the present study aims to investigate the threshold effect of financial stress in the relationship between global crude oil price volatility spillovers and the base metals market of listed companies in Iran using the Panel Smooth Transition Regression (PSTR) model.

2. Methodology

Following the studies of Özçelebi et al. (2025), Heilmeram (2025), Chang (2025), Akadiri et al. (2025), and Shahbaz et al. (2024), the present study investigates the threshold effect of financial stress in the relationship between global crude oil price volatility spillovers and the base metals market of listed companies. The general form of the Panel Smooth Transition Regression (PSTR) model is specified as follows:

$$Metal_{it} = \alpha_0 + \beta_1 OILSH_{it} + \beta_2 FSI_{it} + \beta_3 SIZE_{it} + \beta_4 K_{it} + \beta_5 L_{it} + (\theta_1 OILSH_{it} + \theta_2 FSI_{it} + \theta_3 SIZE_{it} + \theta_4 K_{it} + \theta_5 L_{it})F(S_{it}, \gamma, c$$

where the transition function $F$is defined as:

$$F(S_{it}, \gamma, c) = (1 + \exp\{-\gamma(s_{it} - c)\})^{-1}, \gamma > 0 \qquad (2)$$

To examine the characteristics of the PSTR model with a logistic transition function based on the model proposed by Van Dijk (1999), it is assumed that the dependent variable $Metal$depends solely on its lagged values. Under the assumption of a two-regime transition function, the following relationship is obtained:

$$Metal_t = (\theta_0 + \theta_1 Metal_{t-1} + \cdots + \theta_p Metal_{t-p}) + (\phi_0 + \phi_1 Metal_{t-1} + \cdots + \phi_p Metal_{t-p})G(Metal_t, \gamma, c) + u_t \qquad (3)$$

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

The results derived from this specification are referred to as a two-regime PSTR model, in which the location parameter $c$represents the transition point between the two extreme regimes, namely $G(FSI_t, \gamma, c) = 0$and $G(FSI_t, \gamma, c) = 1$, where $G(FSI_t, \gamma, c) = 0.5$. The parameter γindicates the speed of transition between regimes, and larger values of γimply a more rapid regime shift.

Dependent Variable

$Metal$: Base metals prices.

Independent Variables

L: logarithm of labor input.

K: logarithm of capital input, measured by total fixed assets.

$OILSH$: oil price volatility estimated using ARCH and GARCH models.

$SIZE$: firm size, measured as the logarithm of total corporate assets.

Financial Stress Index (FSI)

The Financial Stress Index (FSI) is calculated using the Principal Component Analysis (PCA) method. The PCA approach reduces the dimensionality of all observations based on a composite index and classifies similar observations into common components. In this method, variables existing within a multidimensional correlated space are summarized into a set of uncorrelated components, each of which is a linear combination of the original variables. The resulting uncorrelated components are referred to as Principal Components (PCs), which are derived from the eigenvectors of the covariance matrix or correlation matrix of the original variables. Reducing the number of variables and identifying the structural relationships among variables are among the most important applications of PCA. The principal advantage of this method in econometrics is the elimination of multicollinearity in models with a large number of influential variables. Subsequently, a composite index based on the volatility of the aforementioned variables is estimated and introduced as an indicator of economic uncertainty.

In the present study, financial stress in the Iranian economy is examined within three sectors, namely the monetary sector, the foreign exchange sector, and the government sector, and is ultimately incorporated into the regression framework using the smooth transition threshold approach.

To calculate the stress index in the government sector, three variables are employed: government expenditures to gross domestic product (GDP), government tax revenues to GDP, and government revenues to GDP. In this regard, the Hodrick–Prescott filtering method is first used to separate the fluctuations of these variables from their long-term trends, after which their negative deviations are ranked between zero (lowest stress) and one hundred (highest stress).

Another important sector of the economy is the monetary sector, which has attracted substantial attention in many studies due to its dominant role in financing activities. In various studies, including those conducted by Stona et al. (2018), Aboura and Van Roye (2017), and Dargahi (2010), the variables commonly utilized include the ratio of currency in circulation to money supply, the ratio of money supply to liquidity, the ratio of short-term deposits to long-term deposits, the ratio of deposit balances to nominal GDP, the ratio of changes in non-government debt balances owed to banks relative to GDP, and the real deposit interest rate. These six variables are also employed in the current study. An increase in the ratio of currency in circulation to money supply above its trend level indicates an increase in cash-based transactions and a decline in the use of demand deposits in economic exchanges. Such an increase reduces the money multiplier and consequently weakens banks' lending capacity, reflecting declining confidence in the banking system or insufficient banking sector development in facilitating transactions. Therefore, an increase in this ratio above its trend is considered a signal of financial stress. In the present study, to estimate stress within the monetary sector, the Hodrick–Prescott filtering method is first applied to separate the fluctuations of the six variables from their long-term trends, and then their negative deviations are ranked between zero (lowest stress) and one hundred (highest stress).

Another market with substantial stress-generating capacity in the Iranian economy is the foreign exchange market. According to the literature, including studies such as Tohidi et al. (2021) and Heydarian et al. (2019), and considering extensive empirical evidence in this field, the production and consumption structure of Iran is highly dependent on imports. Based on studies such as Stona et al. (2018), Dargahi and Nikjoo (2010), and Heydari et al. (2019), two variables, namely the exchange rate premium and the real exchange rate, are used to represent the economy's stress-generating capacity. The exchange rate premium, defined as the difference between the official exchange rate and the free-market exchange rate, is one of the key indicators for measuring stress in the foreign exchange market. The implementation of a multiple exchange rate regime creates distortions in the efficient allocation of foreign currency resources. To extract the stress index, the maximum exchange rate premium is assigned a value of one hundred, whereas the minimum value is assigned zero. In addition, to estimate stress in the real exchange rate, the fluctuations of the variable are extracted from the long-term trend and subsequently ranked between zero and one hundred.

For modeling purposes, annual data from base metals companies listed on the stock exchange are utilized, including Alumtek, Alumrad, Sadid Equipment, Mineral Processing Company, Calcimin, Sadid Industrial Group, Aluminum Rolling Company, Steel Parts Rolling Company, National Lead and Zinc Company, and National Iranian Copper Industries Company over the 2013–2024 period. The data sources used in this study include the Energy Balance Sheet, databases of the National Iranian Gas Company, reports of the National Iranian Oil Products Distribution Company, and the CODAL stock exchange database.

3. Findings and Results

Table 1 presents the results of this test for the variables used in this article. According to the obtained results, the variables are stationary at level, and the absolute value of the Levin, Lin, and Chu statistic is smaller than the absolute values of the critical values of this statistic at the 1%, 5%, and even 10% significance levels. Therefore, all variables are integrated of order zero, $I(0)$.

Table 1. Results of the Unit Root Test

Variable	Coefficient	LLC Statistic	Significance Level	Order of Integration
Base metals prices	Metal	-6.854	0.0000	$I(0)$
Oil price volatility	OILSH	-4.624	0.0011	$I(0)$
Financial stress	FSI	-7.751	0.0000	$I(0)$
Capital	K	-5.364	0.0000	$I(0)$
Labor force	L	-3.741	0.0021	$I(0)$
Firm size	SIZE	-8.391	0.0000	$I(0)$

To examine whether the relationship among the model variables is linear or nonlinear, it is necessary to determine whether m, the number of regime parameters, equals one. It should be noted that in the following tests, the null hypothesis assumes that the model is linear, while the alternative hypothesis corresponds to a logistic PSTR model ($m = 1$)or an exponential PSTR model ($m = 2$). The diagnostic test results presented in Table 2 indicate that the linearity of the model, as the null hypothesis, is rejected. Therefore, a nonlinear relationship exists between global crude oil price volatility spillovers and the base metals market of listed companies in the presence of the threshold effect of financial stress. Accordingly, the PSTR method should be used to estimate the model parameters.

Table 2. Results of the Linearity Hypothesis Test of the Model (BBC Test)

Listed Companies	Null Hypothesis	F Statistic	Significance Level
	Wald test	5.714	0.000
	Fisher test	3.578	0.001
	LRT test	2.214	0.012

As shown by the test results in Table 2, the hypothesis of a linear relationship among the variables is rejected; therefore, the possibility of a linear relationship among the variables is ruled out. It should also be noted that the PSTR model proposed through the selected transition variable is chosen as the optimal model for estimating the model in the selected countries possessing mineral resources and base metals. For this purpose, following González et al. (2005) and Colletaz and Hurlin (2006), the null hypothesis of the existence of a PSTR specification with one transition function was tested against the alternative hypothesis of a PSTR specification with at least two transition functions. The results are presented in Table 3. The findings show that the null hypothesis regarding the adequacy of including one transition function is not rejected in either the one-threshold or two-threshold cases. Therefore, one transition function is sufficient to specify the nonlinear behavior between global crude oil price volatility spillovers and the base metals market.

Table 3. Test of Remaining Nonlinearity

Model Specification	LR Statistic	LMF Statistic	LMW Statistic
Two-threshold case ((M = 2))	0.532	0.684	0.771
p-value	(0.652)	(0.612)	(0.532)
One-threshold case ((M = 1))	0.663	0.527	0.436
p-value	(0.602)	(0.661)	(0.752)

After confirming the existence of a nonlinear relationship among the variables and the adequacy of one transition function for specifying nonlinear behavior, the optimal case between a transition function with one threshold and one with two thresholds must be selected. For this purpose, the PSTR model corresponding to each of these cases was estimated, and based on the criteria of the residual sum of squares, Schwarz criterion, and Akaike criterion, the PSTR model with one threshold was identified as the optimal model. Therefore, a PSTR model with one transition function and one threshold was selected to examine the nonlinear behavior among the variables under study.

In this study, the effects of independent variables, including oil price volatility, financial stress, labor force, gross fixed capital, and firm size, on the base metals prices of Iranian listed companies were examined using the Panel Smooth Transition Regression (PSTR) model. The analyses indicate that some variables have positive effects and others have negative effects on base metals prices, and the intensity of these effects changes when the financial stress index exceeds the threshold level. In the linear component of the model, the effects of the variables are relatively direct and stable; however, upon entering the nonlinear component and passing the threshold level, the effects are intensified or moderated. Overall, oil price volatility and financial stress have negative effects, whereas labor force, fixed capital, and firm size have positive effects. However, the intensity of these effects changes under high financial stress conditions, and the interactions among the variables become more complex. Oil price volatility is one of the most important factors affecting base metals prices.

In the Iranian economy, base metals industries are highly energy-dependent, and changes in oil prices directly affect production costs and firms' profitability. In the linear component of the model, an increase in oil volatility increases risk and production costs and reduces base metals prices. In the nonlinear component, once the financial stress index exceeds the threshold level, the intensity of this negative effect increases, and prices become more sensitive while the market response becomes faster. In other words, each unit increase in oil volatility under high financial stress conditions leads to a greater decline in base metals prices, revealing the interaction between energy and the base metals market. Financial stress, as the threshold variable of the model, plays a decisive role in determining the intensity of the effects of other variables. At low levels of financial stress, the effects of the variables are relatively linear and controlled; however, after crossing the threshold, the effect of financial stress is sharply intensified, and the decline in base metals prices becomes more pronounced. An increase in the financial stress index reduces confidence in financial and investment markets, restricts access to financial resources, and increases market volatility, ultimately making the response of base metals prices more severe and nonlinear.

Labor force has a positive and direct effect on base metals prices because an increase in the quantity and quality of labor enhances firms' production and productivity. In the nonlinear component, when financial stress exceeds the threshold level, the positive effect of labor is slightly moderated, because financial constraints and disruptions in investment may prevent the full utilization of labor. Nevertheless, the overall effect remains positive, and the role of labor in strengthening base metals product prices is maintained. Gross fixed capital, as an indicator of production capacity and corporate infrastructure, also has a positive effect on base metals prices in the linear component. Investment in machinery and production equipment increases productivity, reduces costs, and strengthens firms' competitive capacity. In the nonlinear component, after financial stress exceeds the threshold level, the positive effect of fixed capital decreases to some extent, because financial constraints and severe market fluctuations limit firms' ability to fully exploit capital. However, its positive effect remains, and larger companies are less affected by this decline. Firm size also maintains its positive effect in the linear component. Large firms with greater assets have more resources and flexibility to cope with market volatility and pressure caused by financial stress. In the nonlinear component, crossing the financial stress threshold strengthens the positive effect of firm size, because larger firms are better able to manage price declines and market volatility and maintain stable performance.

Table 4. Model Estimation Using the PSTR Model

Model Component	Variable	Coefficient	Standard Deviation	t Statistic	Probability
Linear component	CONSTANT	0.279373	0.113819	2.454542	0.0145
Linear component	OILSH	-0.131183	0.012286	-10.67710	0.0000
Linear component	FSI	-0.237455	0.018496	-12.83819	0.0000
Linear component	K	0.413355	0.025235	16.38056	0.0000
Linear component	L	0.325380	0.153198	2.123916	0.0370
Linear component	SIZE	0.075534	0.028238	2.674897	0.0092
Nonlinear component	CONSTANT	0.841031	0.100110	8.401060	0.0000
Nonlinear component	OILSH	-0.378627	0.096270	-3.932970	0.0005
Nonlinear component	FSI	-0.368889	0.088200	-4.182405	0.0003
Nonlinear component	K	0.136991	0.031688	4.323084	0.0000
Nonlinear component	L	0.146443	0.042723	3.427765	0.0010
Nonlinear component	SIZE	0.044428	0.010798	4.114412	0.0001
Transition parameter	Threshold C	0.139098	0.04321	3.219115	0.0000
Transition parameter	Slope parameter γ	0.541328	0.286480	1.889580	0.0593

The threshold value of the transition variable in the model is estimated at 13%. In the Panel Smooth Transition Regression (PSTR) model, the effects of variables on base metals prices can be examined in two distinct regimes, and the level of financial stress, as the transition variable, determines the prevailing regime. Based on the estimates, the threshold value of financial stress for listed companies is approximately 0.13. This means that when financial stress is below the threshold, the model is in the linear regime, and the response of the base metals price index to changes in financial stress is limited. However, once financial stress exceeds the 13% threshold and enters the nonlinear regime, the effect of financial stress on base metals prices increases sharply. This finding indicates that when financial stress rises, listed base metals companies and policymakers make more active efforts to preserve market stability through financial stress management and counteractive policies. In other words, as financial stress increases, base metals price management mechanisms and volatility control instruments operate more intensively, and the base metals price index responds more strongly to changes in financial stress. These results emphasize that financial stress management plays a key and nonlinear role in maintaining the stability of base metals prices, and its importance becomes more pronounced under high-risk conditions.

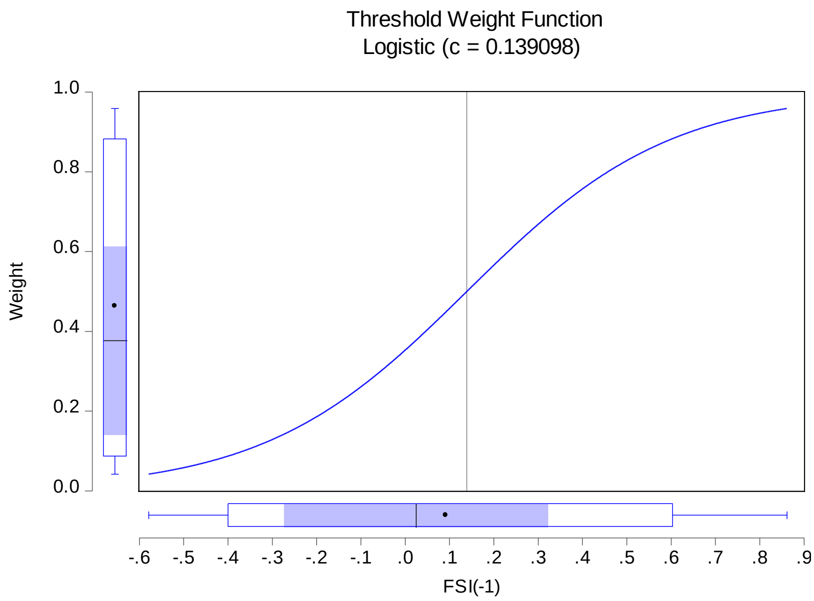

Figure 1. Relationship Between the Transition Function and the Financial Stress Transition Variable

In the present study, the Durbin–Watson test is used to examine autocorrelation.

Table 5. Results of the Autocorrelation Test

	F Statistic	Prob.	Durbin–Watson
Listed companies	1.352	0.74	2.012

As shown in the table above, the results of the Durbin–Watson autocorrelation test indicate that there is no correlation among the disturbance terms. Therefore, the third classical standard assumption, namely the absence of autocorrelation among the error terms, is not violated. Accordingly, the estimators possess the required properties, including minimum variance and efficiency. Another classical standard assumption is homoscedasticity. In the present study, the Breusch–Pagan–Godfrey test is used.

Table 6. Results of the Heteroscedasticity Test

	F Statistic	Prob.	Breusch–Pagan–Godfrey
Listed companies	1.458	0.563	1.412

As shown in the table, the test results indicate the absence of heteroscedasticity.

Another appropriate measure for evaluating the quality of the estimated model is the examination of coefficient changes between the two regimes. If the estimated model is appropriate, the coefficients are expected to remain stable and unchanged across regime shifts.

Table 7. Results of the Smooth Transition Parameter Stability Test

	Null Hypothesis	F Statistic	Prob.
Listed companies	$b_1 = b_2 = b_3 = b_4 = 0$	0.632	0.752
Listed companies	$b_1 = b_2 = b_3 = 0$	0.645	0.732
Listed companies	$b_1 = b_2 = 0$	0.785	0.652
Listed companies	$b_1 = 0$	0.791	0.521

As shown in the table, the coefficient stability test between the two regimes indicates that the coefficients do not change as a result of regime shifts.

4. Discussion and Conclusion

The findings of the present study demonstrated that global crude oil price volatility spillovers exert a significant and nonlinear effect on the base metals market of listed companies in Iran and that financial stress plays a critical threshold role in intensifying or moderating these effects. The results confirmed that oil price volatility and financial stress negatively affect base metals prices, whereas labor force, gross fixed capital, and firm size exert positive effects on the market performance of listed base metals companies. More importantly, the findings revealed that when financial stress exceeds the estimated threshold level, the intensity of the negative effects associated with oil price volatility increases considerably, while the positive effects of productive and structural variables become partially constrained. These findings confirm the existence of nonlinear dynamics in commodity markets and demonstrate that the interaction between oil shocks and industrial metals cannot be adequately explained within a purely linear framework. The results are consistent with the growing literature emphasizing that commodity markets exhibit regime-dependent behavior, particularly during periods of financial instability and elevated uncertainty [8-10].

The negative effect of oil price volatility on the base metals market can be explained through several economic mechanisms. In energy-intensive industries such as copper, aluminum, zinc, and steel production, fluctuations in oil prices directly affect transportation costs, electricity prices, production expenses, and the cost structure of firms. In the Iranian economy, where industrial sectors remain highly dependent on energy inputs and imported technology, increases in oil market uncertainty generate higher production risks and lower profitability. Consequently, investors react negatively to oil shocks, which leads to reductions in market value and instability in base metals prices. This finding aligns with previous studies indicating that oil price shocks significantly influence industrial metals returns and volatility spillovers [1, 4, 5]. Similarly, studies examining commodity interconnectedness report that energy and metal markets display strong co-movements due to common macroeconomic drivers and global investment behavior [6, 22]. The findings of the present study also support the argument that volatility transmission becomes more severe in emerging economies characterized by financial fragility and structural dependence on commodity revenues [23].

Another important finding of the study is the significant negative effect of financial stress on the base metals market. Financial stress reduces market confidence, weakens investment activity, and restricts firms' access to financial resources. Under high levels of financial stress, industrial firms encounter financing constraints, declining liquidity, and increasing uncertainty regarding future market conditions. As a result, production decisions, capital investment, and export activities become more vulnerable to external shocks. The estimated threshold effect indicates that once financial stress surpasses a critical level, the reaction of the base metals market becomes substantially stronger and more nonlinear. This result suggests that financial stress does not merely affect the market independently but also amplifies the transmission of oil price volatility into industrial sectors. Such findings are highly consistent with studies emphasizing the importance of financial conditions and institutional channels in commodity-dependent economies [13, 19]. Research on natural resource economies has similarly demonstrated that weak institutional structures and unstable financial systems increase the sensitivity of industrial markets to external commodity shocks [15, 18].

The threshold behavior identified in this study further confirms the theoretical arguments of nonlinear market dynamics and regime-switching behavior in commodity markets. In periods of low financial stress, the relationship between oil price volatility and base metals prices remains relatively moderate and predictable. However, once the financial stress index exceeds the estimated threshold, market reactions intensify sharply. This phenomenon can be attributed to declining investor confidence, banking sector inefficiencies, tighter credit conditions, and increasing speculative behavior during periods of uncertainty. Under such conditions, firms become less capable of absorbing external shocks, and commodity markets exhibit stronger volatility spillovers. These findings support the conclusions of studies demonstrating that market connectedness and volatility transmission become significantly stronger during crisis periods and unstable regimes [2, 7]. The results are also aligned with the argument that geopolitical risk and economic policy uncertainty amplify market instability and commodity price fluctuations [13, 24].

The positive effect of labor force on base metals prices indicates the importance of human capital and productive capacity in industrial performance. An increase in labor quantity and quality enhances operational efficiency, production capacity, and industrial competitiveness, which ultimately contributes to improved market performance. In resource-intensive industries, skilled labor can increase technological adaptation, reduce production inefficiencies, and strengthen firms' resilience against external shocks. However, the findings revealed that the positive effect of labor force becomes weaker once financial stress exceeds the threshold level. This result may reflect the fact that financial instability constrains firms' ability to fully utilize labor resources due to declining investment, reduced production activity, and limitations in working capital. Nevertheless, the overall positive contribution of labor force remains significant even in nonlinear regimes. This finding is consistent with studies emphasizing the role of productive capacities and industrial sophistication in improving economic resilience in resource-rich economies [29, 33].

Gross fixed capital also exhibited a positive effect on the base metals market, confirming the importance of infrastructure, machinery, and industrial investment in enhancing firms' productivity and competitiveness. Investment in fixed assets improves production efficiency, lowers operational costs, and increases firms' ability to respond to fluctuations in market demand. However, under high financial stress conditions, the positive effect of capital becomes relatively weaker because firms face increasing financing difficulties and reduced access to investment resources. This finding reflects the importance of stable financial systems and institutional support in sustaining industrial investment during periods of economic uncertainty. Previous studies similarly argue that financial development and institutional quality significantly influence the effectiveness of productive investment in resource-rich economies [12, 16]. The findings are also consistent with the literature on economic complexity, which suggests that economies characterized by stronger productive structures and technological capacities are more resilient to commodity shocks and volatility spillovers [27, 28].

The positive effect of firm size identified in the study indicates that larger firms possess greater flexibility and stronger capacities to cope with market volatility and financial stress. Large firms typically have more diversified financial resources, better access to credit markets, and more advanced risk management strategies. Consequently, they are better able to withstand external shocks and maintain stable performance during periods of uncertainty. Interestingly, the results demonstrated that the positive effect of firm size becomes stronger when financial stress exceeds the threshold level. This finding implies that larger firms benefit from economies of scale, stronger institutional relationships, and superior adaptive capacities under crisis conditions. Such evidence supports the argument that structural characteristics of firms significantly influence their resilience against commodity market shocks and financial instability [26, 30].

The findings of this study also contribute to the broader literature on institutional quality and resource-dependent economies. Institutional quality plays a central role in determining how economies respond to external shocks, manage resource revenues, and stabilize financial markets. Economies characterized by efficient institutions, transparent governance, and developed financial systems are generally more capable of mitigating the adverse effects of commodity price volatility. In contrast, institutional weaknesses intensify uncertainty, reduce investment efficiency, and increase financial vulnerability. The nonlinear effects identified in this study suggest that financial stress may partly reflect institutional inefficiencies within the economic system. These findings support earlier studies indicating that institutional quality mediates the relationship between natural resources, economic complexity, and financial development [21, 31, 32]. Likewise, research has shown that weak institutional quality often prevents resource-rich economies from converting resource revenues into sustainable industrial development [17, 35].

Another important implication of the findings relates to the concept of economic complexity and industrial diversification. Economies that rely heavily on oil revenues and commodity exports are generally more vulnerable to external shocks because of their limited productive diversification. In contrast, economies characterized by higher economic complexity and diversified industrial structures possess greater adaptive capacities and lower sensitivity to commodity price volatility. The results of the present study indirectly support this argument by showing that productive factors such as labor force, capital accumulation, and firm size mitigate some of the negative effects associated with oil price volatility and financial stress. This finding aligns with studies emphasizing that industrial complexity and productive diversification can transform natural resources from a curse into a source of sustainable development [26, 36]. Furthermore, research has demonstrated that export diversification and economic sophistication enhance resilience against financial and commodity-related shocks [28, 33].

Overall, the present study provides empirical evidence that the relationship between global crude oil price volatility spillovers and the base metals market is nonlinear and strongly conditioned by financial stress. The findings highlight the importance of considering threshold effects, institutional quality, productive capacities, and financial stability when analyzing commodity-dependent industries. The results also demonstrate that financial stress acts as an amplifying mechanism that intensifies the transmission of oil shocks into industrial markets. Therefore, effective financial management, institutional reforms, and industrial diversification policies are essential for reducing vulnerability to external commodity shocks and improving the resilience of resource-dependent economies such as Iran.

One limitation of the present study is that the analysis focused exclusively on listed base metals companies in Iran, which may limit the generalizability of the findings to other industrial sectors or economies with different institutional and financial structures. In addition, the study employed annual data, which may not fully capture short-term fluctuations and high-frequency volatility spillovers in commodity markets. Another limitation is related to the availability of comprehensive firm-level financial and operational data, which restricted the inclusion of additional explanatory variables such as technological innovation, export orientation, and managerial efficiency. Furthermore, although the PSTR model effectively captures nonlinear dynamics, other nonlinear econometric approaches may provide additional insights regarding structural breaks and asymmetric responses.

Future studies are recommended to investigate the relationship between oil price volatility spillovers and industrial commodity markets using higher-frequency data and alternative nonlinear modeling techniques such as Markov-switching models, quantile regression, and machine learning approaches. Researchers may also examine the moderating role of technological innovation, environmental regulations, export diversification, and digital transformation in reducing the vulnerability of industrial sectors to commodity shocks. Comparative studies across different resource-rich economies and industrial sectors would also contribute to a deeper understanding of how institutional quality and financial development influence market resilience under varying economic conditions.

From a practical perspective, policymakers should prioritize the development of financial stabilization mechanisms, institutional reforms, and industrial diversification strategies to reduce the adverse effects of oil price volatility and financial stress on the base metals market. Strengthening banking sector efficiency, improving access to industrial financing, and expanding risk management instruments can enhance firms' resilience during periods of uncertainty. Industrial managers should also invest in technological upgrading, energy efficiency, and workforce development to improve operational flexibility and competitiveness. In addition, promoting long-term investment in productive infrastructure and encouraging export diversification can contribute to greater market stability and sustainable industrial growth.

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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