Regime-Dependent Relationships Between Commodity Price Volatility and Exchange Market Pressure in Commodity-Exporting Countries

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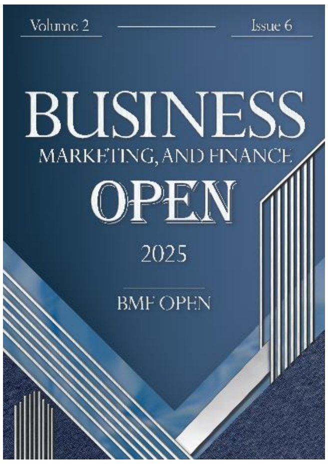

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Abstract: This article examines the nonlinear and regime-dependent relationship between commodity price volatility and exchange market pressure (EMP) in 53 commodity-exporting countries over the period 1980–2023. The principal contribution of the study lies in two aspects: first, the use of the EMP index rather than the real effective exchange rate, thereby providing a more comprehensive representation of pressures in the foreign exchange market; and second, the application of panel quantile regression as a complementary method alongside the Panel Smooth Transition Regression (PSTR) model. The findings indicate that although the PSTR model confirms the existence of a nonlinear relationship, it cannot produce statistically significant coefficients for price volatility. By contrast, quantile regression estimates for five quantiles (0.10, 0.25, 0.50, 0.75, and 0.90) demonstrate that the effect of price volatility is highly dependent on the exchange market pressure regime and the type of commodity. The metals panel, with a coefficient of 0.283 at the 10th percentile, was identified as the most sensitive panel. The raw materials panel exhibits a unique dual pattern, in which price volatility has a stabilizing effect during currency crises but an amplifying effect under high-pressure conditions. In the energy panel, price volatility has an amplifying effect during currency crises but no statistically significant effect under normal conditions. The food panel is the only panel in which price volatility has a stabilizing effect. The findings demonstrate that an accurate understanding of regime dependence and commodity-type dependence is essential for designing effective exchange-rate policies. Based on the results, tailored policy recommendations are proposed for each group of countries, including establishing stabilization funds, reducing fiscal dependence on commodity revenues, diversifying exports, and strengthening central bank independence.

Keywords: exchange market pressure, commodity price volatility, panel quantile regression, Panel Smooth Transition Regression, commodity-exporting countries, regime-dependent effects

1. Introduction

Commodity-exporting countries occupy a distinctive position in the international monetary system because fluctuations in global commodity prices directly affect their export revenues, fiscal balances, external liquidity, capital flows, and exchange-rate dynamics. In economies where a substantial share of foreign exchange earnings originates from energy, metals, food products, or agricultural raw materials, commodity-price movements can rapidly alter the supply of foreign currency and the capacity of monetary authorities to defend the domestic currency. These effects are particularly important when export concentration is high, fiscal revenues depend heavily on commodity-related income, and domestic financial markets lack sufficient depth to absorb external shocks. Under such conditions, commodity-price volatility is not merely a sectoral disturbance; it becomes a macroeconomic and financial shock capable of influencing inflation, output, sovereign risk, international reserves, and the stability of the foreign exchange market. Historical evidence also demonstrates that large external shocks, excessive borrowing during commodity booms, and abrupt reversals in international liquidity have repeatedly contributed to currency and debt crises in resource-dependent economies [1].

The theoretical relationship between commodity prices and exchange rates is commonly explained through the terms-of-trade and wealth channels. An increase in the international price of a country's principal export commodity improves its terms of trade, raises export receipts, increases the supply of foreign currency, and may lead to an appreciation of the domestic currency. Conversely, a decline in commodity prices can reduce foreign exchange revenues, weaken the current account, deplete international reserves, and generate depreciation pressure. Early empirical research on oil and exchange rates established that persistent movements in real oil prices can explain a substantial proportion of long-term real exchange-rate fluctuations, particularly in economies whose production and trade structures are closely linked to energy markets [2]. This argument was subsequently generalized through the concept of "commodity currencies," according to which the real exchange rates of commodity-exporting economies respond systematically to movements in the international prices of their primary exports [3]. Long-run evidence from a broad sample of commodity-dependent countries similarly indicates that real commodity prices are important determinants of equilibrium real exchange rates, although the magnitude and persistence of the relationship vary considerably across countries and commodity groups [4].

Despite this theoretical foundation, the relationship between commodity prices and currency-market conditions is neither uniform nor necessarily linear. The effects of commodity-price changes may differ according to the direction, size, and persistence of the shock; the degree of export concentration; the exchange-rate regime; the level of international reserves; and the financial structure of the exporting economy. Commodity-price increases may strengthen the domestic currency through higher export revenues, but they may also intensify macroeconomic volatility by encouraging procyclical public expenditure, credit expansion, capital inflows, and excessive reliance on temporary windfall revenues. Price declines, in turn, may generate a disproportionate adverse effect when governments and firms have accumulated foreign-currency liabilities during boom periods. Accordingly, the same commodity-price shock may produce different exchange-market consequences across tranquil periods, episodes of moderate pressure, and full-scale currency crises. The structure of the commodity price–exchange rate relationship is therefore likely to be heterogeneous across countries, time periods, and market regimes [5].

The increasing financialization of commodity markets has further complicated these transmission mechanisms. The growing participation of institutional investors, hedge funds, index traders, and other financial intermediaries has strengthened the interaction between commodity prices, exchange rates, international portfolio allocation, and global risk sentiment. Commodity prices are no longer determined solely by physical supply and demand conditions; they are also influenced by financial expectations, liquidity conditions, portfolio rebalancing, and changes in risk aversion [6]. As a result, a commodity-price movement may coincide with capital-flow adjustments and exchange-rate changes that reinforce or offset the conventional trade channel. Evidence concerning asymmetric dependence also suggests that exchange rates play different roles during commodity-market expansions and contractions and that the strength of dependence becomes more pronounced in extreme market conditions [7].

These developments imply that mean-based and symmetric empirical models may conceal important distributional features of the relationship between commodity-price volatility and currency-market pressure.

A substantial body of empirical research has examined the interaction between energy prices and exchange rates. Oil prices are particularly important because oil is simultaneously a major export commodity, a critical production input, an internationally traded financial asset, and a central determinant of global inflation and external balances. Research on energy-exporting countries has shown that energy-price movements affect real exchange rates through trade balances, income effects, government expenditure, and international investment flows [8]. Other evidence demonstrates that the relationship between oil prices and the U.S. dollar is sensitive to the empirical specification, sample period, and treatment of endogeneity, suggesting that the direction and strength of causality cannot be assumed to remain constant over time [9]. Oil-price changes also interact with exchange rates and broader asset-price dynamics through monetary expectations, global demand conditions, and financial-market adjustments [10]. These findings indicate that the exchange-rate consequences of energy-price volatility should be assessed within a broader framework that captures both external trade effects and financial-market pressures.

The commodity currency literature has generally relied on the real effective exchange rate as the principal dependent variable. Although the real effective exchange rate is useful for assessing competitiveness and long-run equilibrium adjustments, it may not fully capture the intensity of short-run pressure in the foreign exchange market. Monetary authorities can prevent or delay exchange-rate adjustment by selling international reserves, tightening monetary conditions, imposing capital controls, or intervening through other policy instruments. In such circumstances, the observed exchange rate may remain relatively stable even when the foreign exchange market is subject to substantial pressure. The exchange market pressure index addresses this limitation by combining exchange-rate movements with changes in international reserves and, in some formulations, interest-rate adjustments. This approach originated in the currency-crisis literature, in which exchange market pressure was used to identify speculative attacks and crisis episodes that may involve either currency depreciation or substantial reserve losses [11]. EMP therefore provides a more comprehensive measure of foreign exchange stress than the exchange rate alone.

The use of EMP is especially relevant for commodity-exporting countries because these economies often rely on reserve accumulation during commodity booms and reserve depletion during downturns. A favorable commodity-price shock may increase export receipts and enable the central bank to accumulate international reserves while limiting nominal appreciation. Conversely, an adverse shock may force the authorities to sell reserves to smooth depreciation, protect financial stability, or service external obligations. Consequently, a model based exclusively on observed exchange-rate changes may underestimate the actual pressure generated by commodity-price volatility. The external balance-sheet position of a country is also critical because the stock and composition of foreign assets and liabilities influence the economy's capacity to withstand commodity and currency shocks. Comprehensive estimates of international investment positions have shown substantial differences across countries in net foreign assets, gross external liabilities, and exposure to valuation effects [12]. Such differences may cause countries facing similar commodity-price shocks to experience markedly different levels of exchange market pressure.

Empirical studies focusing directly on EMP provide evidence that commodity shocks can materially affect currency-market stability. In the Iranian economy, oil-price shocks have been found to influence the EMP index by altering foreign exchange receipts, reserve availability, fiscal conditions, and expectations regarding the domestic currency [13]. Evidence from metal-exporting economies similarly indicates that volatility in base-metal prices can significantly affect exchange market pressure, particularly where mining exports account for a large proportion of foreign exchange revenues [14]. Economies dependent on raw-material exports are also vulnerable to global price fluctuations because their production structures, fiscal systems, and external accounts are often insufficiently diversified [15]. These studies confirm the relevance of commodity-specific analysis, but they also suggest that the magnitude and direction of the relationship may vary considerably across energy, food, metals, and raw materials.

Cross-country studies have further demonstrated that the effect of commodity-price volatility on exchange rates depends on economic structure and the nature of the exported commodity. Research on commodity-exporting developing countries has identified a meaningful relationship between global commodity-price volatility and the real effective exchange rate, while emphasizing the roles of trade openness, external dependence, and domestic macroeconomic conditions [16]. The volatility of commodity prices may alter the conventional terms-of-trade–exchange rate nexus because uncertainty affects investment, consumption, precautionary reserve holdings, and policy responses. Evidence shows that accounting for volatility can materially change the estimated relationship between terms of trade and real exchange rates in commodity-exporting economies [17]. Consequently, examining only the level or direction of commodity-price changes may be insufficient; the instability and unpredictability of those prices constitute an independent source of exchange-market risk.

More recent studies have emphasized nonlinear adjustment. The effects of commodity-price volatility may remain limited within a normal range but become substantially stronger after a financial, institutional, or macroeconomic threshold is crossed. A Panel Smooth Transition Regression framework allows coefficients to vary gradually between regimes according to a transition variable and is therefore well suited to identifying such nonlinearities. Using this approach, previous research has documented a nonlinear relationship between real commodity-price volatility and the real effective exchange rates of commodity-exporting countries [18]. The effect of volatility was found to depend on financial integration, indicating that greater integration may alter the transmission of commodity shocks through cross-border capital flows and domestic financial markets. Related evidence based on separate price indices for food, metals, energy, and raw materials has also shown that exchange market pressure responds differently across commodity categories and economic regimes [19]. These findings represent an important departure from homogeneous linear specifications.

Nevertheless, the PSTR approach has certain limitations when the effects of explanatory variables differ across the entire conditional distribution of exchange market pressure rather than only between a small number of estimated regimes. A single-threshold logistic transition function imposes a particular form of nonlinear adjustment and may not adequately capture sharp asymmetries in the tails of the EMP distribution. This issue is especially important because currency crises are located in the lower tail, whereas strong appreciation pressures and large foreign exchange inflows are represented in the upper tail. An average coefficient may therefore combine fundamentally different responses and produce an insignificant estimate even when the effect is economically substantial in specific parts of the distribution. Quantile regression offers a useful solution because it estimates the conditional effect of commodity-price volatility at different quantiles of EMP without assuming that the relationship is identical across low-, median-, and high-pressure regimes.

The use of quantile-based methods has become increasingly important in research on commodity and financial markets because the effects of uncertainty and volatility are often concentrated in extreme conditions. Recent evidence based on nonparametric quantile-on-quantile analysis indicates that oil-price uncertainty and exchange-rate volatility can have heterogeneous effects across different states of financial markets, particularly in African economies exposed to external commodity and currency shocks [20]. Although that study focuses on stock markets, its methodological implication is directly relevant to exchange market pressure: the effect of an external shock at one point in its distribution may vary according to the position of the affected variable within its own distribution. Applying this logic to EMP makes it possible to distinguish between currency-crisis regimes, relatively tranquil conditions, and episodes of severe upward pressure on the domestic currency.

Commodity-type heterogeneity is also theoretically important. Energy exporters frequently benefit from large and concentrated foreign exchange inflows but remain vulnerable to abrupt oil-price collapses, procyclical fiscal policy, and dependence on hydrocarbon revenues. Metal exporters face global industrial-demand cycles and may be exposed to the foreign-currency liabilities of large mining corporations. Food exporters are influenced by the relatively inelastic demand for essential goods, domestic food-security concerns, and the macroeconomic consequences of supply shocks. Raw-material exporters often constitute a heterogeneous group in which exports and imports may both contain substantial quantities of intermediate commodities. These structural differences imply that a given increase in price volatility may amplify exchange market pressure in one commodity group while producing a stabilizing effect in another. They also imply that the direction of the effect may reverse between crisis and high-pressure regimes.

The distinction between stabilizing and amplifying effects has direct policy significance. When commodity-price volatility amplifies exchange market pressure during crises, policymakers may need larger precautionary reserves, countercyclical stabilization funds, more conservative external borrowing policies, and stronger macroprudential regulation. When the effect is concentrated in high-EMP regimes, measures aimed at managing excessive appreciation, volatile capital inflows, and Dutch disease become more relevant. In countries where commodity volatility produces stabilizing effects through lower import demand or automatic expenditure adjustment, policy intervention should be designed carefully to avoid offsetting beneficial adjustment mechanisms. The appropriate response therefore depends not only on the existence of a commodity-price effect but also on the commodity group, the prevailing EMP regime, and the financial and external position of the economy.

Despite extensive research on commodity currencies, several gaps remain. First, much of the literature examines real effective exchange rates rather than a broader EMP indicator incorporating reserve changes. Second, many studies impose linear or mean-based specifications that cannot identify heterogeneous effects in the tails of the EMP distribution. Third, analyses frequently focus on oil or an aggregate commodity index and consequently overlook differences among energy, food, metals, and raw materials. Fourth, relatively few studies combine threshold-based panel estimation with panel quantile regression to distinguish structural nonlinearity from distributional heterogeneity. Addressing these gaps can provide a more accurate explanation of why similar commodity-price shocks produce currency crises in some countries, appreciation pressure in others, and limited observable effects under normal conditions.

Accordingly, the aim of this study is to examine the nonlinear, regime-dependent, and commodity-specific effects of price volatility on exchange market pressure in 53 energy-, food-, metal-, and raw-material-exporting countries over the 1980–2023 period by combining Panel Smooth Transition Regression and panel quantile regression methods.

2. Methodology

In this study, the exchange market pressure (EMP) index is calculated in accordance with the standard approach adopted in the literature (Eichengreen et al., 1996; Reinhart & Rogoff, 2009), as follows:

$$EMP_{i,t} = \frac{\Delta e_{i,t}}{\sigma_e} - \frac{\Delta r_{i,t}}{\sigma_r}$$

where $\Delta e_{i,t}$ denotes the percentage change in the nominal exchange rate, $\Delta r_{i,t}$ represents the percentage change in international reserves, and σ_e and σ_r denote the standard deviations of changes in the exchange rate and international reserves, respectively. Positive EMP values indicate upward pressure, that is, appreciation of the domestic currency, whereas negative values indicate downward pressure, that is, depreciation of the domestic currency.

The principal independent variable is commodity price volatility, which, following the approach of Boubakri et al. (2019), is calculated as the absolute value of the logarithmic change in the real commodity price index:

$$Volatility_{i,t}^{c} = \left|\ln\left(P_{i,t}^{c}\right) - \ln\left(P_{i,t-1}^{c}\right)\right| \times 100$$

where $P_{i,t}^{c}$ denotes the real price index of commodity category c—energy, food, metals, or raw materials—in year t. The control variables include the Balassa–Samuelson effect, $\Delta LBS_{i,t}$; commodity terms of trade, $TOT_{i,t}^{c}$; and financial integration, $(M2/GDP)_{i,t}$. The data sources are reported in Table 1.

Table 1. Research Variables and Data Sources

Variable	Data source	Description
EMP (exchange market pressure)	IMF International Financial Statistics (IFS)	Calculated on the basis of changes in exchange rates and international reserves
REER (real effective exchange rate)	Bank for International Settlements (BIS) and Bruegel	Index: 2010 = 100
Commodity price indices	World Bank Commodity Price Data (Pink Sheet)	Real price indices for energy, food, metals, and raw materials
NFA (net foreign assets)	External Wealth of Nations database (Lane & Milesi-Ferretti)	Percentage of GDP
M2/GDP	World Development Indicators (WDI)	Principal measure of financial integration
GDP per capita (PPP)	World Development Indicators (WDI) and IMF World Economic Outlook (WEO)	Used to calculate the Balassa–Samuelson effect
TOT (trade openness)	IMF World Economic Outlook (WEO)	Used to calculate the terms of trade

This study employs two complementary empirical methods. The first is the Panel Smooth Transition Regression (PSTR) model, which, following Boubakri et al. (2019), is used to confirm the existence of a nonlinear relationship and estimate the threshold value. The PSTR model is defined as follows:

$$EMP_{i,t} = \mu_i + \beta_0' X_{i,t} + \beta_1' X_{i,t} F\left(S_{i,t}; \gamma; c\right) + \varepsilon_{i,t}$$

where $X_{i,t}$ is the vector of explanatory variables, including price volatility, $\Delta LBS_{i,t}$, $TOT_{i,t}^{c}$, and $(M2/GDP)_{i,t}$. The logistic transition function is specified as:

$$F\left(S_{i,t}; \gamma; c\right) = \left[1 + \exp\left(-\gamma\left(S_{i,t} - c\right)\right)\right]^{-1}$$

with the transition variable defined as:

$$S_{i,t} = \frac{M2}{GDP}$$

Here, γ is the slope parameter and c is the threshold parameter.

The second and principal method is quantile regression. Because the EMP variable is negatively skewed and the PSTR model is relatively unable to generate statistically significant coefficients for price volatility, quantile regression is employed as a complementary and innovative method. The quantile regression model is defined as follows:

$$Q_\tau(EMP_{i,t} \mid X_{i,t}) = \alpha_\tau + \beta'_\tau X_{i,t}$$

where

$$Q_\tau(EMP_{i,t} \mid X_{i,t})$$

denotes the τ-th quantile of the conditional distribution of EMP. Quantile regressions are estimated at five quantiles: 0.10, 0.25, 0.50, 0.75, and 0.90. Selecting these five quantiles makes it possible to examine behavior at different points in the EMP distribution, ranging from a currency crisis at $\tau = 0.10$to severe upward pressure at $\tau = 0.90$.

The principal advantage of quantile regression over mean-based models, such as ordinary least squares (OLS) and PSTR, is that it is more robust to the distribution of the error terms and the presence of outliers, while providing a comprehensive representation of the effects of the explanatory variables across the entire distribution of the dependent variable. Given the negative skewness of the EMP variable, which is demonstrated in the descriptive statistics section, this method is more appropriate for the data used in the present study.

3. Findings and Results

Table 2 presents descriptive statistics for the principal variables across the four panels. The mean EMP is positive in all panels and ranges from 3.78 in the energy panel to 4.36 in the food panel. The high standard deviation of EMP, ranging from 42.15 to 43.21, indicates substantial fluctuations in exchange market pressure among commodity-exporting countries. The negative skewness of EMP in all panels, ranging from -0.05in the food panel to -0.21in the raw materials panel, indicates that the EMP distribution has a heavy left tail characterized by large negative values. This finding justifies the use of quantile regression because mean-based models cannot accurately estimate the effects of explanatory variables in the left tail of the distribution.

The mean price volatility is highest in the metals panel, at 102.60, and lowest in the food panel, at 84.37. The standard deviation of volatility is highest in the food panel, at 33.13, indicating that although food price volatility is relatively low on average, it exhibits substantial dispersion. The mean $M2/GDP$ratio in the energy panel, at 0.687, is higher than that of the other panels.

Table 2. Descriptive Statistics for the Full Sample

Variable	Mean	Standard deviation	Minimum	Maximum	Skewness	Kurtosis
EMP	6.38	42.75	-99.95	98.41	-0.12	2.84
Price volatility (%)	95.81	28.53	1.90	186.29	0.45	2.56
DLBS	1.23	4.85	-27.20	25.80	-0.56	6.21
ToT	92.34	21.56	45.32	180.21	0.23	3.12
M2/GDP	0.617	0.225	0.249	1.052	0.18	2.34

The PSTR linearity test presented in Table 3 indicates that the null hypothesis of linearity is rejected in all four panels, with $p < 0.10$in each panel. This finding confirms that the relationship between commodity price volatility and exchange market pressure is nonlinear and that linear models are insufficient for analyzing this relationship.

Table 3. Results of the PSTR Linearity Test

Panel	LMF statistic ($\boldsymbol{m} = \mathbf{1}$)	$\boldsymbol{p}$-value	Result
Energy	3.06	0.038	Linearity rejected
Food and beverages	5.73	<0.001	Linearity rejected
Metals	3.61	0.069	Linearity rejected at the 10% level
Raw materials	11.27	<0.001	Linearity rejected

Nevertheless, when the coefficients of the final PSTR model were estimated, the price-volatility coefficients were not statistically significant in any of the panels, as shown in Table 4. This finding indicates that although the overall structure of the relationship is nonlinear, the PSTR model, with its single-threshold specification and logistic transition function, cannot fully capture this nonlinearity. Consequently, priority is given to the quantile regression results as the complementary and innovative methodological component of this study.

Table 4. Summary of PSTR Model Results: Price-Volatility Coefficients

Panel	Regime 1 coefficient	Regime 2 coefficient	Linearity-test $\boldsymbol{p}$-value
Energy	0.0929	0.0203	0.1324
Food and beverages	0.0135	-0.0685	0.1486
Metals	0.0846	0.1214	0.2398
Raw materials	0.1015	0.1400	0.2088

The quantile regression results provide substantial and informative evidence. Given the large number of estimated results, Table 5 summarizes the statistically significant coefficients, while Table 6 presents the complete coefficient matrix.

Table 5. Quantile Regression Results: Summary of Statistically Significant Coefficients

Panel	Quantile	Coefficient	$\boldsymbol{p}$-value	Direction of effect
Metals	$Q = 0.10$	0.283	0.024	Positive, amplifying
Metals	$Q = 0.25$	0.195	0.089	Positive, amplifying
Raw materials	$Q = 0.10$	-0.242	0.033	Negative, stabilizing
Raw materials	$Q = 0.75$	0.247	0.001	Positive, amplifying
Raw materials	$Q = 0.90$	0.149	0.053	Positive, amplifying
Energy	$Q = 0.10$	0.225	0.003	Positive, amplifying
Food	$Q = 0.50$	-0.095	0.063	Negative, stabilizing
Food	$Q = 0.75$	-0.118	0.013	Negative, stabilizing
Food	$Q = 0.90$	-0.087	0.047	Negative, stabilizing

The results presented in Tables 5 and 6 indicate that the metals panel exhibits the greatest sensitivity among all panels. The coefficient of price volatility at the 10th percentile, corresponding to currency-crisis conditions, is 0.283 and is statistically significant at the 5% level. At the 25th percentile, the coefficient is 0.195 and statistically significant at the 10% level. At the higher quantiles of 0.50, 0.75, and 0.90, the coefficients are not statistically significant. This pattern indicates that the effect of metal price volatility on exchange market pressure is asymmetric and adverse: it is significant only during currency crises and under relatively low-pressure conditions, while losing statistical significance under normal and high-pressure conditions.

Table 6. Matrix of Price-Volatility Coefficients Across Quantiles

Panel	$\boldsymbol{Q = 0.10}$	$\boldsymbol{Q = 0.25}$	$\boldsymbol{Q = 0.50}$	$\boldsymbol{Q = 0.75}$	$\boldsymbol{Q = 0.90}$
Energy	0.225*	0.018	-0.010	0.033	-0.062
Food	-0.073	-0.049	-0.095*	-0.118*	-0.087*

Metals	0.283*	0.195*	0.120	0.094	-0.006
Raw materials	-0.242*	-0.030	0.065	0.247*	0.149*

The raw materials panel exhibits the most distinctive and noteworthy pattern. The price-volatility coefficient at the 10th percentile, corresponding to currency-crisis conditions, is $-0.242$and statistically significant at the 5% level. At the 75th percentile, representing high-pressure conditions, the coefficient is 0.247 and statistically significant at the 1% level. At the 90th percentile, representing very high pressure, the coefficient is 0.149 and statistically significant at the 10% level. At the 25th and 50th percentiles, the coefficients are not statistically significant. This dual pattern demonstrates that the sign of the effect of raw material price volatility on exchange market pressure depends on the level of exchange market pressure. In other words, price volatility has a stabilizing effect during crises, reducing pressure, but an amplifying effect under high-pressure conditions, increasing pressure.

Similar to the metals panel, the energy panel exhibits a positive and statistically significant effect at the 10th percentile. The coefficient at this quantile is 0.225 and statistically significant at the 1% level. The coefficients at all other quantiles are not statistically significant. This finding indicates that energy price volatility has an amplifying effect during currency crises but has no statistically significant effect on EMP under normal or high-pressure conditions. The absolute magnitude of the coefficient in the energy panel, 0.225, is smaller than that in the metals panel, 0.283, indicating that although energy-exporting countries are vulnerable, they are not as vulnerable to price volatility as metal-exporting countries.

The food and beverages panel is the only panel in which the coefficients are negative and statistically significant. The coefficient at the 50th percentile is -0.095, which is statistically significant at the 10% level; the coefficient at the 75th percentile is -0.118, which is statistically significant at the 5% level; and the coefficient at the 90th percentile is -0.087, which is statistically significant at the 5% level. The largest coefficient in absolute terms occurs at the 75th percentile, at -0.118. This finding indicates that food price volatility has a stabilizing effect at moderate to high levels of exchange market pressure and reduces upward pressure on the domestic currency.

Figure 1 illustrates the price-volatility coefficients at different quantiles for the four groups under examination. As shown in the figure, the coefficient of energy price volatility is positive and statistically significant only at the 10th percentile, which corresponds to currency-crisis conditions. The coefficients at the other quantiles are not statistically significant. Food price volatility has a negative and statistically significant effect on EMP at moderate to high EMP levels, namely at the 0.50, 0.75, and 0.90 quantiles. The largest negative coefficient occurs at the 0.75 quantile. The negative coefficient at the 0.75 quantile indicates that when EMP is relatively high, reflecting upward pressure on the domestic currency, an increase in food price volatility reduces this pressure. An increase in food prices therefore represents a negative supply shock. This negative supply shock reduces production and national income. Lower national income reduces the demand for imports, including luxury and intermediate goods. A decline in import demand implies a reduction in the demand for foreign currency, thereby relieving pressure on the domestic currency. In other words, food price volatility operates as a self-stabilizing mechanism.

The negative coefficient at the 0.90 quantile also indicates that the negative effect persists under extremely high-pressure conditions, defined as $EMP > 50$, although its absolute magnitude is smaller than at the 0.75 quantile. This finding suggests that under extremely high-pressure conditions, other mechanisms, such as central bank intervention, may become operative and moderate the effect. Finally, the statistically insignificant coefficient at the 0.10 quantile indicates that under currency-crisis conditions characterized by very low EMP, food price volatility has no statistically significant effect on EMP. This result suggests that economic priorities change during crises and that fluctuations in the price of food, which is generally an essential good, may not have an immediate effect on the foreign exchange market because demand for food is relatively price-inelastic.

The metals panel exhibits the greatest sensitivity among all panels. Metal price volatility has a positive and statistically significant effect on EMP at the lower quantiles, specifically the 0.10 and 0.25 quantiles. The largest coefficient occurs at the 0.10 quantile, indicating that under currency-crisis conditions characterized by very low EMP, metal price volatility leads to a substantial increase in exchange market pressure. This is the largest coefficient among all panels, demonstrating that metals constitute the commodity sector most sensitive to foreign exchange shocks. The coefficient at the 0.25 quantile also indicates that the positive effect persists under relatively low-pressure conditions, although its absolute magnitude is smaller than at the 0.10 quantile. This finding indicates that as foreign exchange market conditions improve and EMP moves toward less negative values, the amplifying effect of metal price volatility declines. The statistically insignificant coefficients at the 0.50–0.90 quantiles indicate that metal price volatility has no statistically significant effect on EMP under normal or high-pressure conditions. This finding demonstrates that the transmission of metal price volatility to the foreign exchange market is an asymmetric mechanism that becomes active only under adverse conditions, particularly currency crises. Several factors may explain the high sensitivity of metals. First, export dependence is substantial. The economies of metal-exporting countries, such as Chile, where copper accounts for approximately 50% of exports, are highly dependent on global metal prices. These countries derive a substantial share of their foreign exchange revenues from metal exports. Second, the balance-sheet effects of large mining companies are important. Mining companies generally obtain substantial foreign-currency-denominated loans, particularly in U.S. dollars. A decline in metal prices reduces these companies' foreign exchange revenues and undermines their ability to repay foreign-currency-denominated debt. This situation may increase demand for foreign currency for debt repayment and consequently lead to depreciation of the domestic currency. Third, an expectations effect may arise. Severe fluctuations in metal prices can influence the expectations of economic agents, resulting in capital outflows and increasing pressure on the domestic currency.

The raw materials panel exhibits a dual, U-shaped pattern. The effect of price volatility is negative at low EMP levels and positive at high EMP levels. At the 0.10 quantile, corresponding to very low EMP and severe currency-crisis conditions characterized by substantial depreciation, an increase in raw material price volatility reduces exchange market pressure. This result may be explained by several mechanisms. First, depreciation of the domestic currency reduces individuals' real wealth because their purchasing power in international markets declines. This decline in wealth reduces the demand for imports. Second, many raw-material-exporting countries are themselves importers of industrial raw materials; for example, they may import cotton and export textiles. Domestic currency depreciation increases import prices and reduces import demand. Third, the overall effect of reduced demand for foreign currency, resulting from lower imports, outweighs the effect of increased export revenues resulting from higher global raw material prices. Consequently, exchange market pressure declines. At the 0.75 and 0.90 quantiles, which represent high EMP conditions, the domestic currency is subject to upward pressure and is appreciating. Under these conditions, increased raw material price volatility further intensifies pressure. An increase in raw material prices raises the foreign exchange revenues of exporting countries. Under favorable economic conditions characterized by upward currency pressure, foreign investors seek investment opportunities. Increased foreign exchange revenues from raw material exports enhance the attractiveness of the economy and lead to greater capital inflows. Capital inflows further appreciate the domestic currency, which in turn encourages additional capital inflows. Raw material price volatility intensifies this positive feedback mechanism. The statistically insignificant coefficients at the 0.25 and 0.50 quantiles indicate that under normal EMP conditions, raw material price volatility has no statistically significant effect on EMP. This finding suggests that automatic adjustment mechanisms function effectively under normal conditions.

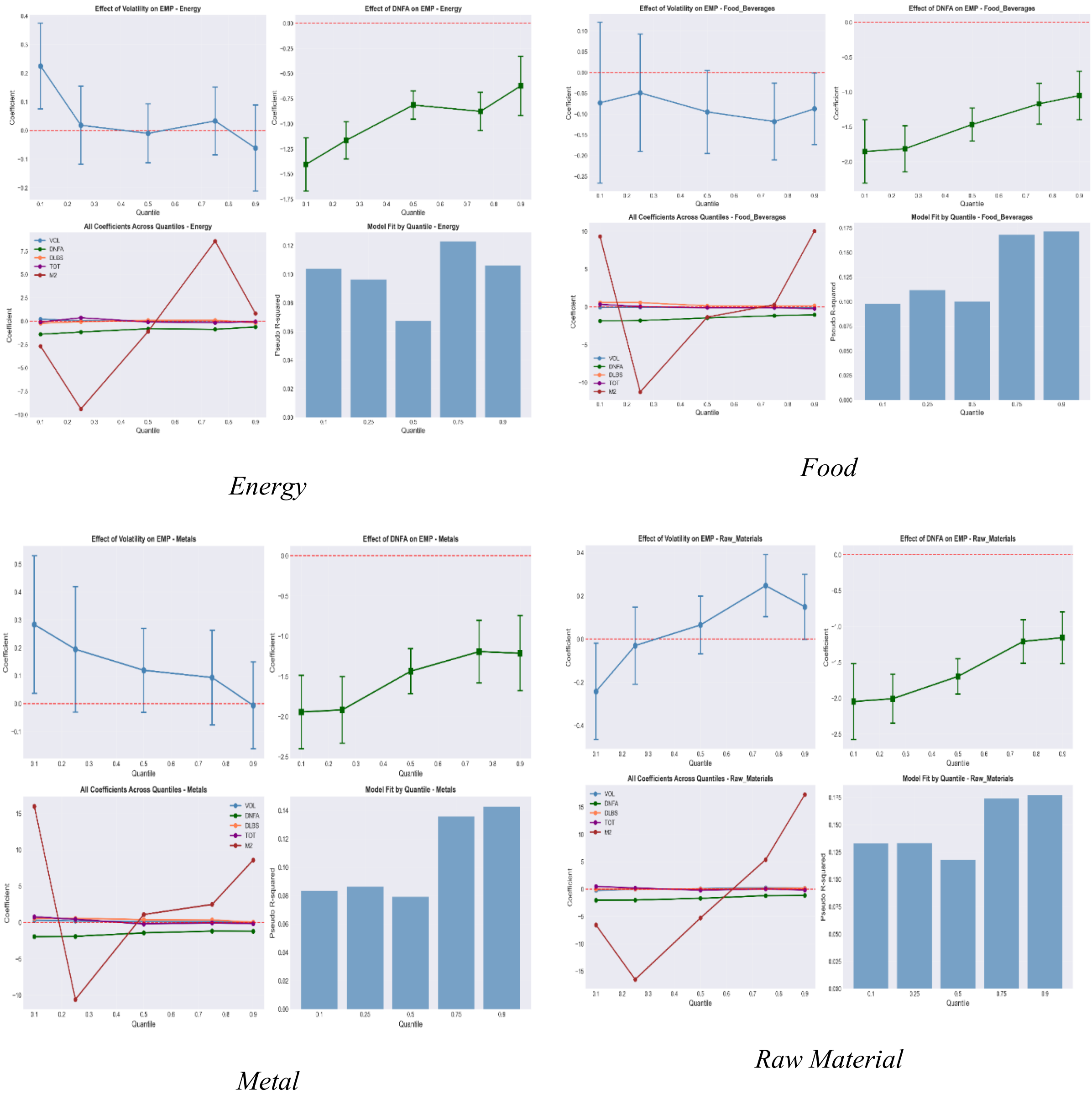

Figure 1. Price-Volatility Coefficients Across Quantiles

Figure 2 presents the matrix of price-volatility coefficients across all quantiles for the four panels in the form of a heatmap. The heatmap facilitates a rapid visual comparison across panels and quantiles. Dark red represents large positive coefficients, dark blue represents large negative coefficients, and white represents coefficients close to zero.

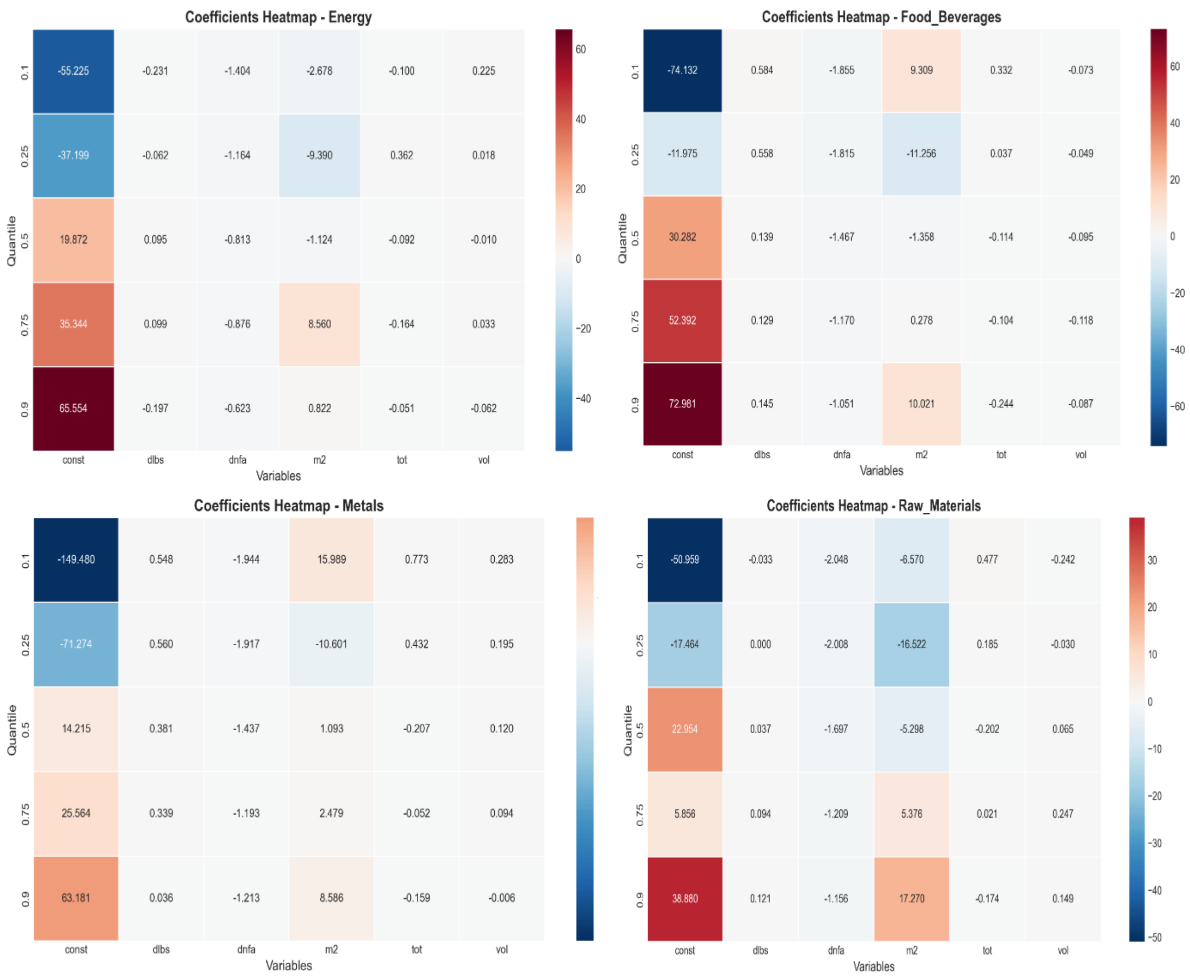

Figure 2. Heatmap of Coefficients

The heatmap clearly demonstrates that, in the energy group, the dark-red cell for the volatility coefficient at the 0.10 quantile represents a large positive value of 0.225. The green or blue cells at the other quantiles indicate values close to zero. The orange cell for ToT at the 0.25 quantile represents a positive and statistically significant coefficient of 0.362, indicating that the terms of trade are important only at low EMP levels. In the food group, the dark-green cells for the volatility coefficients at the 0.50, 0.75, and 0.90 quantiles represent negative values ranging from $-0.095$to -0.118. The red cell for ToT at the 0.10 quantile corresponds to a coefficient of 0.332. Although this coefficient is not strictly statistically significant, it is close to conventional significance levels, suggesting that under crisis conditions, an improvement in the terms of trade may have a positive effect on EMP. Therefore, increased food price volatility under normal and high-pressure conditions reduces exchange market pressure and produces a stabilizing effect. This finding can be explained through the logic of a negative supply shock: an increase in food prices reduces economic activity and lowers demand for domestic currency.

In the metals group, the heatmap indicates that the ToT coefficient is positive and statistically significant at the lower quantiles, highlighting the importance of the terms of trade during currency crises. Metal-dependent economies, such as Chile, Peru, and Zambia, are highly dependent on global commodity prices. During currency crises characterized by low EMP, positive fluctuations in metal prices increase foreign exchange revenues and consequently intensify pressure on the domestic currency. Finally, in the raw materials group, the $M2/GDP$coefficient is positive and statistically significant at the 0.90 quantile, indicating that under high-pressure conditions, financial integration may have an amplifying effect. The raw materials panel includes the most heterogeneous group of countries. Its dual pattern demonstrates that the effect of raw material price volatility depends on the exchange market pressure regime. During severe crises, volatility has a stabilizing effect, whereas under high-pressure conditions, it has an amplifying effect.

4. Discussion and Conclusion

The present study examined the nonlinear and regime-dependent relationship between commodity price volatility and exchange market pressure across 53 commodity-exporting countries over the period 1980–2023. The empirical findings provide three principal insights. First, the rejection of linearity in all four commodity panels confirms that the relationship between commodity price volatility and exchange market pressure cannot be adequately represented by a constant linear coefficient. Second, although the Panel Smooth Transition Regression model detected nonlinear adjustment, the estimated price-volatility coefficients were not statistically significant in the final PSTR specifications, indicating that a single-threshold transition structure could not fully capture the heterogeneity embedded in the distribution of exchange market pressure. Third, the panel quantile regression results revealed pronounced differences across commodity groups and EMP regimes. Metal and energy price volatility intensified exchange market pressure primarily in the lower tail of the EMP distribution, food price volatility exerted a stabilizing effect in the middle and upper quantiles, and raw material price volatility displayed a dual pattern, with a stabilizing effect during severe currency crises and an amplifying effect under high-pressure conditions.

The rejection of linearity across all panels is consistent with the broader literature emphasizing that commodity-price and exchange-rate relationships are state-dependent, asymmetric, and sensitive to macroeconomic conditions. Earlier studies based on conventional linear models established the existence of a relationship between commodity prices and exchange rates, particularly in commodity-exporting countries [3, 4]. However, subsequent research showed that the strength and direction of this relationship differ across market states and cannot necessarily be summarized by a single average effect [5, 17]. The present findings reinforce this argument by demonstrating that the exchange-market consequences of commodity price volatility differ substantially between crisis regimes, normal conditions, and episodes of strong upward pressure. They also support the view that commodity-currency dynamics are shaped not only by changes in commodity prices but also by the degree of volatility, the structure of the exporting economy, and the prevailing financial regime.

The nonlinear results are particularly aligned with the evidence reported by Boubakri et al., who identified a nonlinear relationship between real commodity price volatility and the real effective exchange rates of commodity-exporting countries and showed that financial integration plays an important role in regime transition [18]. The present study extends that line of research in two respects. First, it replaces the real effective exchange rate with exchange market pressure, thereby incorporating changes in international reserves in addition to exchange-rate movements. Second, it shows that even after nonlinearity is established through PSTR, the precise effect of volatility may remain concealed unless different quantiles of the EMP distribution are examined. This explains why the PSTR model identified structural nonlinearity but did not yield statistically significant price-volatility coefficients. The response of EMP is not merely divided into two smooth regimes; rather, the sign and magnitude of the effect vary across different parts of the conditional distribution.

The suitability of the EMP index is also supported by the currency-crisis literature. A country may experience significant foreign exchange pressure without an immediate large exchange-rate movement when the central bank intervenes through reserve sales or other defensive measures. Consequently, an exchange-rate-only indicator may underestimate actual market pressure. The EMP framework originally developed in the analysis of speculative attacks and contagious currency crises captures this broader adjustment mechanism [11]. The relevance of this measure is especially pronounced in commodity-exporting countries, where central banks often accumulate reserves during price booms and use them to defend the domestic currency during downturns. Historical evidence further shows that external shocks, reserve depletion, excessive borrowing, and sudden changes in investor confidence frequently interact during episodes of financial distress [1]. Therefore, the use of EMP provides a more comprehensive interpretation of commodity-related currency vulnerability.

The panel quantile regression findings demonstrate that the lower tail of the EMP distribution is particularly important for energy- and metal-exporting economies. In the energy panel, the coefficient of price volatility was positive and statistically significant only at the 0.10 quantile. This result indicates that energy price volatility intensifies exchange market pressure during currency-crisis conditions but has no statistically significant effect under normal or high-pressure regimes. This finding is consistent with studies showing that oil-price shocks affect exchange rates through export revenues, fiscal balances, current-account positions, and expectations [2, 8]. It is also aligned with evidence that oil-price shocks significantly influence exchange market pressure in oil-dependent economies, particularly when foreign exchange earnings and government revenues are closely tied to hydrocarbon exports [13].

The concentration of the energy effect in the crisis quantile can be explained by the asymmetric consequences of oil-price volatility. During normal periods, energy-exporting countries may absorb price fluctuations through sovereign wealth funds, accumulated reserves, flexible fiscal policies, or exchange-rate intervention. During a currency crisis, however, these buffers may be weakened or insufficient. A decline or abrupt fluctuation in energy prices can reduce export receipts, worsen fiscal expectations, increase sovereign-risk perceptions, and intensify demand for foreign currency. This interpretation is consistent with evidence that the oil price–exchange rate relationship varies across time and depends on global monetary conditions, asset prices, and market expectations [9, 10]. The statistically insignificant results in higher quantiles suggest that when the currency is stable or under appreciation pressure, other adjustment channels may neutralize the effect of energy price volatility.

The metals panel exhibited the largest positive coefficient in the study, with a value of 0.283 at the 0.10 quantile, followed by a positive coefficient at the 0.25 quantile. This indicates that metal-exporting economies are the most sensitive to commodity price volatility under severe and moderately adverse exchange-market conditions. The finding is consistent with previous evidence that base-metal price volatility can significantly affect exchange market pressure in metal-exporting countries [14]. It also corresponds with research showing that the relationship between global commodity price volatility and real effective exchange rates is particularly strong in developing economies with concentrated commodity-export structures [16].

Several mechanisms may account for the pronounced vulnerability of metal-exporting economies. First, metal exports are frequently concentrated in a limited number of products, such as copper, iron ore, zinc, or aluminum, which exposes foreign exchange revenues to global industrial cycles. Second, mining projects often require substantial foreign-currency financing. When metal prices become volatile or decline, the balance sheets of mining companies deteriorate, while their foreign-currency obligations remain unchanged. This mismatch can increase demand for foreign currency and intensify depreciation pressure. Third, metal prices are closely linked to expectations concerning global growth and industrial demand. Abrupt price changes may therefore signal deteriorating international conditions and trigger capital outflows. These mechanisms are compatible with the broader argument that the commodity price–exchange rate relationship is shaped by financial-market expectations and cannot be explained solely through current export revenues [5].

The stronger metal coefficient relative to the energy coefficient also suggests that the institutional buffers available to oil exporters may be more developed than those available to many metal exporters. Several energy-exporting economies have established sovereign wealth funds, stabilization arrangements, and formal reserve-management frameworks. By contrast, many metal-exporting developing countries remain highly exposed to corporate external debt, concentrated fiscal revenues, and volatile private capital flows. Consequently, similar commodity-price volatility may translate into greater exchange-market pressure in the metals panel. This result supports the broader proposition that the impact of commodity shocks depends on the structure of external assets and liabilities [12]. Countries with stronger net foreign asset positions and larger liquid reserve buffers may be better able to absorb volatility than countries with substantial foreign-currency liabilities.

The food and beverages panel produced a markedly different pattern. Food price volatility had negative and statistically significant coefficients at the 0.50, 0.75, and 0.90 quantiles. Thus, food price volatility exerted a stabilizing effect at moderate and high levels of EMP. This result differs from the amplifying effects identified in the energy and metals panels and confirms that commodity-type heterogeneity is a central feature of the relationship. The finding is consistent with research showing that different commodity categories generate distinct exchange-market effects and should not be aggregated into a single commodity-price measure [19]. It also reflects the argument that the structure of dependence between commodity prices and exchange rates varies across commodity markets [7].

The stabilizing effect of food price volatility may operate through domestic demand and import-compression channels. Rising or volatile food prices can generate a negative supply shock, increase production costs, reduce real household income, and weaken aggregate demand. Lower real income may reduce demand for imported consumer and intermediate goods, thereby decreasing demand for foreign currency. Because food is generally a necessity with relatively inelastic demand, the domestic adjustment may occur through reductions in other expenditures, particularly imports. In this way, food price volatility can reduce foreign exchange demand and moderate upward pressure on the domestic currency. The stronger negative coefficient at the 0.75 quantile suggests that this adjustment is most effective when EMP is relatively high but not yet at an extreme level.

At the 0.90 quantile, the food-price coefficient remained negative but decreased in absolute magnitude. This may indicate that when upward pressure becomes exceptionally strong, central bank intervention, capital-flow management, or changes in trade policy begin to dominate the automatic demand-adjustment mechanism. The absence of a significant coefficient at the 0.10 quantile also suggests that food price volatility is not a primary determinant of exchange-market pressure during severe currency crises. Under such conditions, capital flight, debt-service obligations, reserve losses, and confidence shocks may outweigh commodity-specific trade effects. This interpretation is compatible with the crisis literature, which emphasizes that extreme foreign exchange pressure reflects the interaction of multiple financial and macroeconomic vulnerabilities rather than a single trade-price shock [1, 11].

The raw materials panel displayed the most complex result. The coefficient was negative and statistically significant at the 0.10 quantile, but positive and significant at the 0.75 and 0.90 quantiles. This U-shaped regime-dependent pattern shows that raw material price volatility has a stabilizing effect during severe currency crises but an amplifying effect when the domestic currency is already under upward pressure. This finding is compatible with evidence that raw-material-exporting economies are highly vulnerable to global price fluctuations, but that their responses differ according to institutional structure and market conditions [15]. It also supports the conclusion that the commodity price–exchange rate nexus is altered by volatility and should be analyzed through models capable of capturing asymmetry [17].

The stabilizing effect in the crisis quantile may be explained by import compression. Many raw-material-exporting countries also import industrial inputs and intermediate commodities. During severe depreciation, the domestic-currency cost of these imports rises sharply, reducing import demand and, consequently, demand for foreign exchange. If this contraction in foreign exchange demand is stronger than the reduction in export receipts, overall exchange market pressure may decline. This mechanism is particularly plausible in lower-income and structurally dependent economies where depreciation rapidly constrains imports and domestic expenditure.

The positive coefficients at the 0.75 and 0.90 quantiles indicate a different mechanism. Under favorable external conditions, higher or more volatile raw material prices may increase export receipts, improve growth expectations, and attract capital inflows. These developments can intensify appreciation pressure. The financialization of commodity markets may reinforce this process because investors respond not only to physical trade conditions but also to commodity-related financial signals and portfolio opportunities [6]. As capital inflows increase, domestic currency appreciation may encourage further inflows, generating a positive feedback mechanism. The raw materials panel therefore illustrates particularly clearly why the same commodity-price shock can have opposite effects across EMP regimes.

The findings also clarify the role of financial integration. Although the study primarily focused on price-volatility coefficients, the significant $M2/GDP$ coefficient at the upper quantile of the raw materials panel suggests that deeper financial integration may amplify exchange-market pressure under already favorable conditions. Financial integration can facilitate international capital inflows during commodity booms, but it can also increase exposure to abrupt reversals. This interpretation is consistent with nonlinear evidence showing that financial integration changes the transmission of commodity-price volatility to exchange rates [18]. It is also compatible with the external-wealth perspective, which emphasizes that gross foreign asset and liability positions shape the sensitivity of national economies to international shocks [12].

More broadly, the results support the use of quantile-based approaches in commodity and exchange-market research. Recent evidence demonstrates that oil-price uncertainty and exchange-rate volatility generate heterogeneous effects across different quantiles and market conditions [20]. The present study confirms that this distributional heterogeneity is also present in exchange market pressure. An insignificant mean coefficient does not necessarily imply the absence of an economically meaningful relationship. Rather, positive effects in one part of the distribution may be offset by negative or insignificant effects elsewhere. Quantile regression therefore reveals information that remains hidden in mean-based models and even in certain threshold specifications.

The findings also contribute to the commodity-currency literature by demonstrating that commodity-price volatility should not be treated as a homogeneous external shock. Earlier studies established that commodity prices are important determinants of real exchange rates [3, 4], while later research emphasized asymmetry, financialization, and nonlinear adjustment [6, 7, 18]. The present results integrate these perspectives by showing that the effect depends simultaneously on the commodity category and the EMP regime. This conclusion helps explain why previous studies have sometimes reported weak, unstable, or contradictory average effects.

This study has several limitations. First, the classification of countries into energy, food, metals, and raw materials panels necessarily simplifies economies that may export more than one major commodity and whose export composition may change over time. Second, annual data may not fully capture short-lived currency-market reactions, speculative attacks, and rapid reserve interventions. Third, the EMP index is based on exchange-rate and reserve movements and does not directly incorporate interest-rate changes, capital controls, or unofficial foreign exchange market conditions. Fourth, cross-country institutional differences, including exchange-rate regimes, fiscal rules, sovereign wealth funds, central bank credibility, and capital-account restrictions, may affect the estimated coefficients but are not modeled comprehensively. Fifth, although panel quantile regression identifies distributional heterogeneity, the results should not automatically be interpreted as establishing strict causal relationships because commodity volatility, capital flows, fiscal responses, and exchange-market conditions may be simultaneously determined.

Future studies should employ higher-frequency monthly or quarterly data to examine the timing and persistence of exchange-market responses to commodity shocks. Country-specific export weights could be used to construct dynamic commodity-price indices that more accurately reflect changes in national export structures. Future models could also distinguish between positive and negative price shocks, expected and unexpected volatility, and temporary and persistent commodity cycles. Incorporating exchange-rate regimes, reserve adequacy, sovereign wealth funds, foreign-currency debt, institutional quality, and central bank independence as transition or interaction variables would clarify why some commodity exporters are more resilient than others. Additional research could apply panel quantile vector autoregression, quantile-on-quantile regression, local projections, or nonlinear causal models to investigate dynamic feedback between commodity prices, capital flows, reserves, and EMP. Separate analyses of advanced, emerging, and low-income commodity exporters would also help identify whether institutional capacity changes the regime-dependent effects.

Policymakers should design commodity-specific exchange-market strategies rather than applying a uniform framework to all exporting economies. Metal- and energy-exporting countries should prioritize reserve adequacy, foreign-currency debt management, countercyclical fiscal rules, and stabilization funds because their vulnerability is greatest during crisis regimes. Governments should limit the use of temporary commodity windfalls to finance permanent expenditures and should strengthen fiscal buffers during periods of high prices. Raw-material-exporting economies should manage both crisis-related import compression and boom-related appreciation pressure through flexible reserve accumulation, macroprudential regulation, and carefully calibrated capital-flow measures. Food-exporting countries should recognize that the observed stabilizing effect may result from reduced domestic demand and should therefore avoid interpreting lower EMP as evidence that food-price volatility is socially or economically harmless. Across all commodity groups, export diversification, deeper domestic financial markets, greater central bank independence, transparent intervention rules, and systematic monitoring of commodity-specific EMP indicators can reduce vulnerability and improve the timing of policy responses.

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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