



Impact of Tariffs and Macroeconomic Factors on US Non-Ferrous Metal Prices: An Empirical Analysis

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Abstract

This paper analyses the factors that determine the prices of the non-ferrous metal in the US, specifically the role of tariffs and important macroeconomic variables. The analysis uses US data, explanatory variables as ferrous metal imports, GDP, exchange rates and tariff rates. A multiple linear regression model is used, and relevant variables are transformed by the use of logarithmic transformation to enhance the model interpretability and model fit. The results indicate that import demand has a strong and statistically strong positive impact on metal prices, but GDP has a positive but insignificant impact relationship. Conversely, tariff rates are statistically non-significant implying that there is only a minimal direct influence on the price movements of metals. Diagnostic tests ensure that there is no heteroskedasticity and autocorrelation, even though signs of possible model misspecification are found. Overall, the findings emphasize the predominance of market fundamentals in price determination of metals over trade policy, making valuable contributions to policymakers and researchers.

Keywords: *Metal Trading; London Stock Exchange; Tariffs, Metal Import; Exchange Rate Dynamics*

Introduction

There is a cointegration between the price of gold and crude oil. The price of gold causally affects crude oil prices and Rupiah exchange rate (Kusnadi & Saragih, 2020). The volatility of metal prices, namely, LME copper price, is in tandem with the volatility of the world GDP growth rate (Huang and Liu, n.d.). The actual exchange rate of the USA is a key variable in shaping the prices of gold, copper and zinc. The world oil price and the world production of copper play an important role in the price of copper (Determinantes Macroeconomicos de Los Precios de Los Principales Commodities Minero Metalicos Del Peru). Una Aproximación Empírica 1990 - 2016, 2019). The 2003-2008 commodity boom was fuelled by rising demand by China, the global mining industry that was rigid in supply and more financial actors that had entered the commodity markets. The consumption of the base metals by China has resulted in disruption of demand in the world commodity markets, and has affected the global mining industry (Farooki, 2010). There was a long-term connection between the GDP of BRICS and six base metal prices

(Aluminum, Copper, Lead, Nickel, Zinc and Tin). BRICs were observed to affect the prices of base metals a bit more than OECD (oserjoin & Kim, 2013). There exists a correlation between the GDP cycles and the commodity-price cycles. There is a short-run causality between GDP and commodity prices, which indicates that the fluctuation of one variable can affect the other in the short-run. Oil prices are also key determinants of metal price cycle fluctuations at all levels (Ojeda-Joya et al., 2015). Metal consumption (Au, Sn, Zn, and W) has also been absolutely decoupled with the growth of the economy and has shown a negative relationship with its consumption per capita when compared to GDP per capita (Halada et al., 2007). Federal funds rates positively relate to metal futures prices, which implies that an increase in interest rates will reduce their prices. There is a significant relationship between imports and dollar prices, which means that changes in the prices of non-ferrous metals, and especially gold and silver, have a significant influence on the imports of Turkey, and consequently on the overall foreign trade balance in 1997-2018. Time-varying effects of shocks in the international nonferrous metal prices on the industrial economy of China are heterogeneous at the various time-horizons, but the largest effects are found in the short term. The negative impacts of international nonferrous metal price shock on industrial added value have serious lag effects, manifested in the medium term and long-term. Producer Price Index (PPI) and industrial employment effect of shock is positive (Zhong et al., 2019). The domination of the London Metal Exchange in the pricing of base metal futures exchanges around the world fell out of favour during the COVID-19 pandemic (Chen & Tongurai, 2024). Moreover, there were shocks in the price of nickel due to demand and supply. Since 1980, the price development has been dominated by nickel-specific demand shocks (Ehrlich, 2018). The trade war between the US and China, which began in March 2018, resulted in serious trade sanctions, such as high tariffs on imported metals. The Chinese metal market has been subjected to drastic changes due to the trade conflict which has impacted negatively on the market stability (Shao, 2023). The US is becoming more dependent on imports to supply its metal requirements although the reliance is decreasing gradually. A possible shift towards the reduction of import dependence is that domestic mineral resources are likely to grow in the future (Prestwich, 2017). Global macroeconomic forces, especially those based on the fictitious economy have become more prominent in determining the prices of nickel since the middle of the 2000s. The influence of the bidding processes on the London Metal Exchange is also recognized as the critical factor that influences the prices of nonferrous metals (Sokolov and Borodina, n.d.). The changes in the prices of the US dollar, oil, gold and silver are felt in the price of copper in China. The external factors cause different changes in the price of metals, and there is a necessity to take steps that would help to reduce the impact of external factors (Liu-guo, 2012). Metal futures prices are negatively correlated with the increase in the federal funds rates which means an increase in interest rates will result in a decline in the prices. A rise in interest rates decreases the liquidity of currency and thus demand for non-ferrous metals is suppressed leading to a decrease in prices (Fan, 2023). The correlations between when a precious metal is cointegrated are not consistent over time. The changes in the price relations are significant during the peaks of the business cycle and recessions (Kucher and McCoskey, 2016). The relationship between transitory shocks (the COVID-19 pandemic and the Russia-Ukraine conflict) and the prices of precious and non-precious metals was found to be positive (van der Nest and van Vuuren, 2023). Investors in U.S. defense companies viewed the introduction of tariffs on the imports of steel and aluminum in a negative way (Online Appendix., 2025). The U.S. has trade surplus in seven other higher-value products of aluminum, which means that the trade deficit is its self-inflicted industrial structure. The introduction of aluminum tariffs in the U.S. could serve to enhance domestic production capacities of high value aluminum products by cutting down the levels of imports (Wang et al., n.d.).

Literature Review

An increment of 1 per cent in gross domestic product (GDP) has the effect of raising the metal footprint by a margin of up to 1.9 per cent in the same year. Each percentage point growth in the gross capital formation as a GDP percentage increases the metal footprint by 2 percent, holding GDP constant

(Zheng et al., 2018). Metal footprint is very responsive to alterations in national GDP. This sensitivity can be largely explained by capital formation (Zheng et al., 2018). An apparent relationship was found between world stock of steel and world GDP indicating that the demand of iron ore in the world depends on the change in GDP but not the quantity of GDP. The movement of primary iron has a significant impact on the world crude steel production (Kozawa & Tsukihashi, 2010). A high correlation was observed between the actual price of aluminium, copper, lead, tin, zinc, gold and silver and the null hypothesis of independence was rejected in all but the gold-lead pair. There was very good evidence of the correlation between the price of gold and the price of aluminium and a significance level of 0.1 percent was slightly less than the level required (Roberts, 2008). Global GDP, world production, and real prices of copper, aluminum, lead, zinc, nickel and tin annual data between 1945 and 2019 showed that the nonferrous metals reacted differently to supply, demand, and commodity-specific demand shocks. Remarkably, the shocks in prices of all metals were mostly driven by the demand shock and not the supply shock as the impulse response function and the historical decomposition analysis show (Choi et al., 2020). The volatility of production of some of the nonferrous metals in the U.S. during the 20th century was very high. The great depression and the two world wars contributed to major changes in production. In the 1980s, world production was not associated with a high price of tin because the International Tin Council attempted to control the price, but failed. The price series of non-ferrous metals in steel production, with a more specific focus on the ones that are traded in the London Metal Exchange, were found to exhibit a significant change in the direction of the causality relationship between the two price series, with a variation of more than a five-fold range in U.S. copper exports in the second half of the century (Piper & Nokleberg, n.d.). Empirical findings reveal that aluminum is a Granger cause of other non-ferrous metal prices implying that the prices of non-ferrous metals are largely driven by the prices of aluminum (Basoglu et al., 2014). Metallic recovery boosts by 10 percent will reduce imports of metallic raw materials by 3.3 percent (Dussaux & Glachant, 2018). There was a significant negative relationship, $p = 0.7+$ between gold and copper with a significant value of over 0.7 percent. Whereas other metals were found to have a less than 0.5 correlation with silver and gold, which means that they co-move especially weakly (Roberts, 2008). The demand of the Chinese has a strong dynamic effect on the international metal prices of non-ferrous metal and a steep variation was experienced in May 2009. This price effect due to the influence of Chinese demand on the prices has been stable since May 2009, meaning that it was entering the stable period after the rising period, according to the Kuznets curve (Zhu, 2015). The forward price and spot price of copper and aluminum are co-integrated, which means that it was in the stable period. The forward and spot price mutually guide each other and this implies that during the US recession, gold is strongly dominant over other precious metals like palladium, platinum and silver (Zhang, 2005). Empirical evidence shows that gold plays a key role over other precious metals (palladium, platinum and silver) during recessions in the US. In the aftermath of the pandemic, it is recognized that gold can be a good hedge against uncertainty on the market (Agnese et al., 2024). The producer price index of metals and metal products rose at an average of 6.7% per year in the upswing signals of the leading index as compared to the 1.7% rates in the other periods. The average price increases of aluminum scrap were 15 percent on upswing signals and a decline during downturns was 11 percent (Moore, 1988). US tariffs on steel and aluminium are likely to reduce the quantity of basic metal products that will be exchanged with the US, especially the countries, such as India, Russia and Turkey. The net effect of the tariffs on GDP and employment is deemed to be insignificant, even though more metal industry is produced in the US (Salotti et al., 2019). Previous studies found out that tariff pass-through of steel goods imported is full, contrary to recent studies that suggest otherwise. Major and massive supply chain changes were experienced after tariffs were imposed on steel products. With these changes, the total imports of steel products had a downward pattern of 34.5 million metric tons in 2017 to 26.3 million metric tons in 2019 (Ahmad and Ahmad, 2023). The tariff policy of protectionism that was introduced in the United States had a structural impact on US imports of steel and aluminum. The June 2018 tariff shock had a negative impact on the quantity and prices of these Mexican imports. Although the United States might be fulfilling its aim of safeguarding its local industry, it might also cause higher local prices of these metals (Becerril Torres et al., 2022).

Methodology

Research Design

The research design of this study is quantitative and tests the relationship between the price of non-ferrous metals used in the US and the various economic variables. The effect of imports, GDP, exchange rates and tariffs on metal prices are estimated using a multiple regression framework.

Area and Scope of Study

The variables are based on United States data since it is largely involved in international metal markets. The analysis utilizes time-series data of about twenty years, on an annual basis.

Data Sources

The analysis has been done with the help of secondary data. The exchange rates and the macroeconomic indicators data were taken from the International Monetary Fund, and GDP data was taken from the World Bank. Further information on metal prices and imports and tariffs are gathered using pertinent international and national databases, which are sourced in the appendix section.

1. Variables Used

The dependent variable was US Non-Ferrous Metal Prices and the independent variables were US Non-Ferrous Metal Imports, Gross Domestic Product, Exchange Rate and Tariff Rate.

2. Data Processing

Interpolation and extrapolation methods were used to fill in missing values in tariff data. Moreover, GDP and metal prices underwent logarithmic transformation to stabilize the variance in order to enhance interpretation of the models.

Model Specification

The regression model that is estimated can be stated as:

$$\ln(\text{MetalPrices}) = \beta_0 + \beta_1(\text{Imports}) + \beta_2(\ln\text{GDP}) + \beta_3(\text{Exchange Rate}) + \beta_4(\text{Tariff}) + \epsilon$$

3. Diagnostic Tests

In order to make sure that the model is reliable, a number of diagnostic tests were carried out like Multicollinearity test using Variance Inflation Factor (VIF), Heteroskedasticity test using Breusch–Pagan test, Autocorrelation test using Breusch–Godfrey LM test, Model specification test using Ramsey RESET test.

Analysis

Table 1
Regression Model

Source	SS	df	MS
Model	1.88421436	3	.628071454
Residual	.497237078	18	.027624282
Total	2.38145144	21	.113402449

Number of obs = **22**
 F(3, 18) = **22.74**
 Prob > F = **0.0000**
 R-squared = **0.7912**
 Adj R-squared = **0.7564**
 Root MSE = **.16621**

ln_price	Coefficient	Std. err.	t	P> t	[95% conf. interval]
YEAR	-.0799356	.0400956	-1.99	0.062	-.16453 .0046588
USNONFERR OUSMETALI MPORTSBI	.0048104	.0013169	3.65	0.002	.002032 .0075888
ln_gdp	2.500948	1.231314	2.03	0.058	-.0968979 5.098794
TARIFFRATE_i	.2506947	.3302119	0.76	0.458	-.4459915 .947381
_cons	86.58103	47.22685	1.83	0.084	-13.0589 186.221

The regression estimates show that the model has a good fit of the data on the whole. The value of R-squared, 0.7912, is an indication that about 79 percent of the change in the non-ferrous metal prices in the US is accounted for by the explanatory variables included. The adjusted R-squared of 0.7564 is relatively high considering the number of predictors, indicating that the model is specified accordingly. Moreover, the F-statistic of 22.74 with p-value of 0.0000 proves that the model is statistically significant as a whole, which means that the independent variables, as a collective, are explanatory.

Looking at the coefficients of individual countries, US non-ferrous metal imports prove to be one of the major factors that determine the prices of metals. The value of the coefficient is positive (0.0048) and statistically significant at the 1% level (= 0.002), which means that the growth in imports is related to the increase in metal prices. This is an indication that demand-side variables which are reflected by the level of imports are significant determinants of price.

The GDP coefficient (logarithmic) is positive (2.50) and significant at the 10% level ($p = 0.058$) marginally. This suggests that economic growth would push up metal prices as it is expected that an improvement in economic activity would boost demand for industrial metals. Equally, the time trend variable (YEAR) is negatively correlated and weakly significant ($p = 0.062$) indicating that there is a slight downward trend in prices within the sample period, but this is not highly robust.

Conversely, the tariff variable (TARIFFRATE_i) does not have a statistically significant value ($p = 0.458$) although its coefficient is positive. This implies that the direct effect of tariffs on the prices of non-ferrous metal used in the US are not measurable under the sample period. A possible reason is that the prices of metals are set more or less in the global markets hence restricting the impact of the country-related trade policies. Also, the lack of variation and interpolated tariff data can also undermine its statistical value.

In general, the results show that macroeconomic and demand-related variables, especially imports and GDP, are more significant to determine the price of metals, whereas trade policy variables, including tariffs, seem to have a less direct impact.

Table 2

Multicollinearity VIF test.

Variable	VIF	1/VIF
ln_gdp	9.28	0.107705
TARIFFR ATE _i	7.27	0.137502
USNONFE RRO~I	3.46	0.289175
Mean VIF		6.67

The results of the Variance Inflation Factor (VIF) indicate moderate multicollinearity to be present in the model. With a mean VIF of 6.67, which is higher than the generally acceptable value of 5, there is indeed a correlation between the independent variables, though not that severe.

Among regressors, the highest VIF value of 9.28 is ln gdp, which is almost equal to the critical value of 10. This means that GDP is strongly connected to other explanatory variables and this might overstate its standard error and decrease the statistical significance of its coefficient.

In a similar vein, VIF of TARIFFrate_i is quite large (7.27), which shows the presence of strong multicollinearity. This could be one of the reasons why it was not statistically significant in the regression outcome even though it was theoretically anticipated to be related with metal prices.

Conversely, the VIF of US non-ferrous metal imports is lower at 3.46, indicating that it is not highly influenced by multicollinearity and its estimates of the coefficients are more accurate.

Generally, there is multicollinearity but it is not extreme to reject the model. Nonetheless, it can undermine the accuracy of some estimations and findings must be handled with care.

Table 3

Breusch–Pagan/Cook–Weisberg test for heteroskedasticity

Assumption: Normal error terms
Variable: Fitted values of \ln_price
H0: Constant variance
 $\chi^2(1) = 0.09$
Prob > $\chi^2 = 0.7689$

The results of the Breusch–Pagan/Cook–Weisberg test indicate that there is no evidence of heteroskedasticity in the model. The null hypothesis of equal variance cannot be rejected since the p-value (0.7689) is much greater than the traditional significance levels (0.05).

The test value ($\chi^2 = 0.09$) is quite low which also leads to the conclusion that the variance of the residuals does not change with observation. This implies that the homoskedasticity assumption holds.

This is generally a positive result of the regression model because it means that the standard errors estimated are accurate. Therefore, statistical inferences made based on the model such as hypothesis tests and confidence intervals can be said to be valid.

Table 4

Breusch–Godfrey LM test for autocorrelation

lags(p)	chi2	df	Prob > chi2
1	2.245	1	0.1340

H0: no serial correlation

The results of the Breusch Godfrey LM test indicate that there is no evidence of autocorrelation in the model. The null hypothesis of zero serial correlation is not rejected because the p-value (0.1340) is more than the standard level of significance (0.05).

The test-value ($\chi^2 = 2.245$) is not very high, which also indicates the lack of the serial correlation of the residuals. This implies that the error terms are not time-dependent.

In general, this is a good result, since this means that the model is not autocorrelated. Thus the estimated coefficients and standard errors can be deemed as reliable and the results of the regression can be inferred.

Table 5

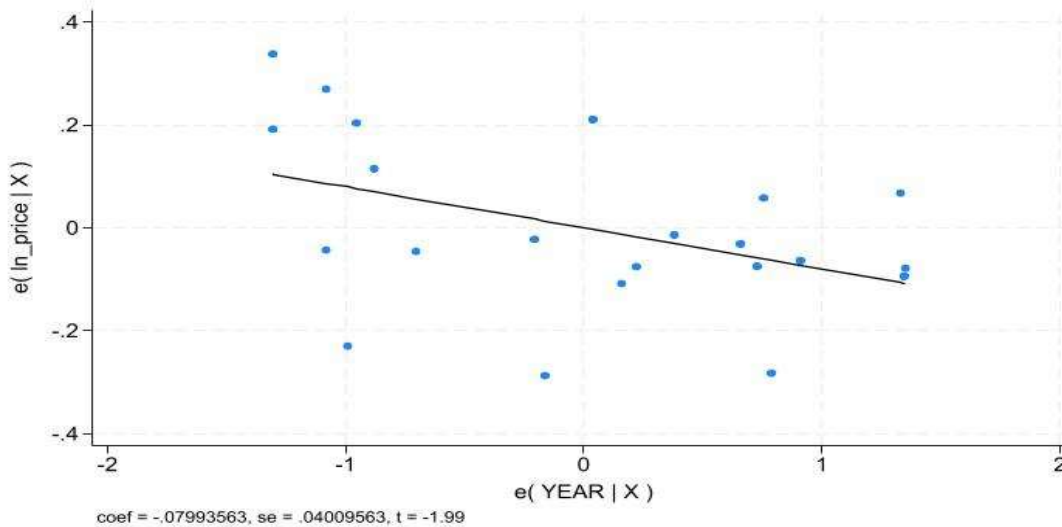
Ramsey RESET test

H0: Model has no omitted variables $F(3, 14) = 7.05$
Prob > $F = 0.0040$

According to the results of the Ramsey RESET test, the model might have specification errors. The null hypothesis that there are no omitted variables is rejected since the p-value (0.0040) is far much less than the traditional level of significance (0.05). This implies that the model might be missing some important variables or that the model is not specified correctly in its functional form.

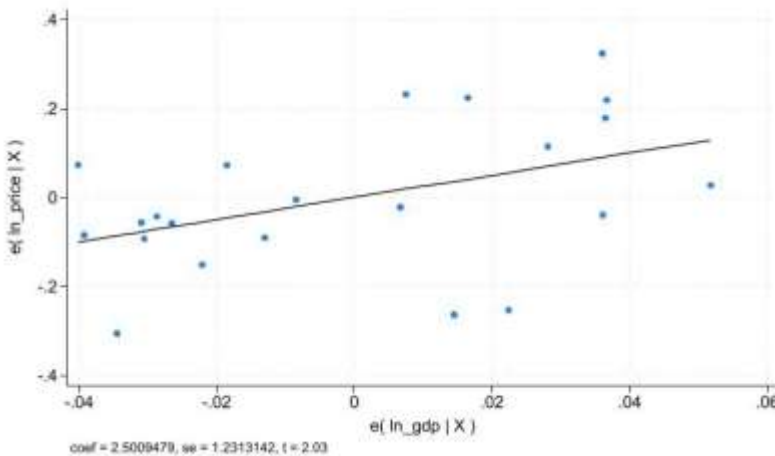
The statistically significant F-statistic ($F = 7.05$) also supports the omitted variable bias or non-linear relationship that is not reflected in the existing model. Specifically, the test suggests that terms of the fitted values of higher order bring about more explanatory power, which suggests the possibility of non-linearity. On the whole, this finding indicates a shortcoming of the model. Although the regression has a high explanatory power, the RESET test indicates that the specification might be imperfect. This may be attributed to economic factors that are not considered like world demand of metals, energy prices or other functional forms. Consequently, care should be taken when interpreting the results and future studies could involve refining the model specification.

Figure 1
Partial regression plot (year and price)



The partial regression plot indicates that there is a negative relationship between YEAR and ln price, with the fitted line having a downward slope. The distribution of points is however quite broad implying a loose correlation. This is in line with regression outcomes, the coefficient is only marginally significant meaning that the time trend does not have much influence on metal prices.

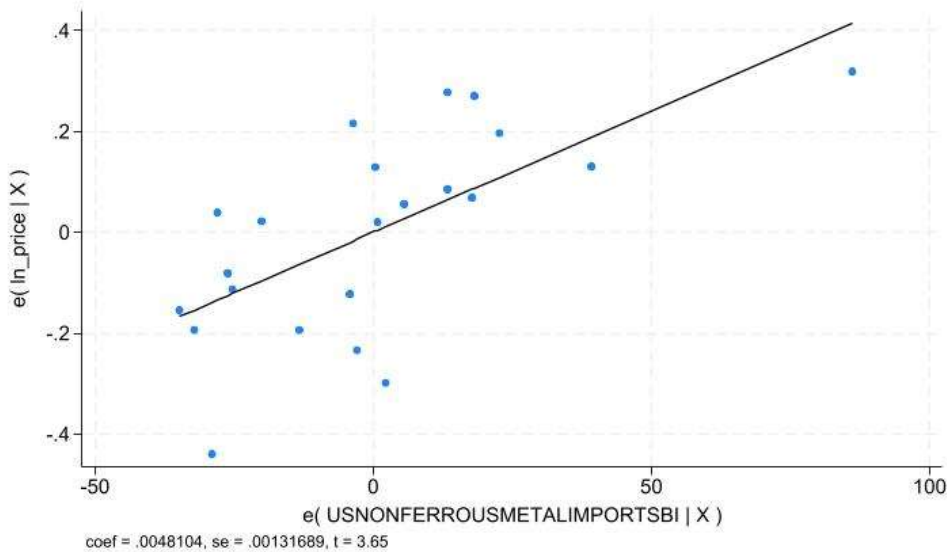
Figure 2
Partial regression plot (GDP and price)



The partial regression plot indicates that there is a positive correlation between \ln gdp and \ln price as indicated by the positive trend of the fitted line. Although the points are slightly spread, the general trend gives an indication that the higher the GDP, the higher the metal prices. This can be found to support the regression results, with a positive and marginally significant impact of GDP.

Figure 3

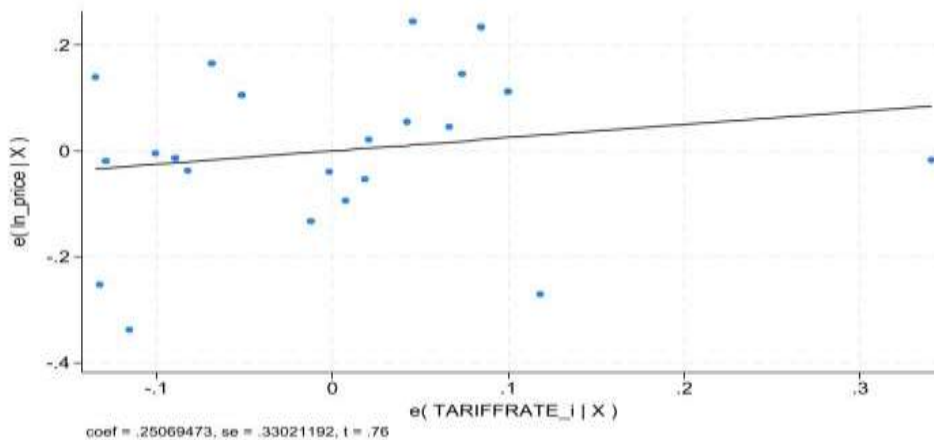
Partial regression plot (US non-ferrous metal imports and price)



The partial regression plot indicates that the relationship between the US non-ferrous metal imports and \ln -price is definitely positive as the fitted line is on an upward trend. The values are fairly consistent with the trend implying a good correlation. This is in line with the regression findings with imports showing a positive and significant impact on metal prices.

Figure 4

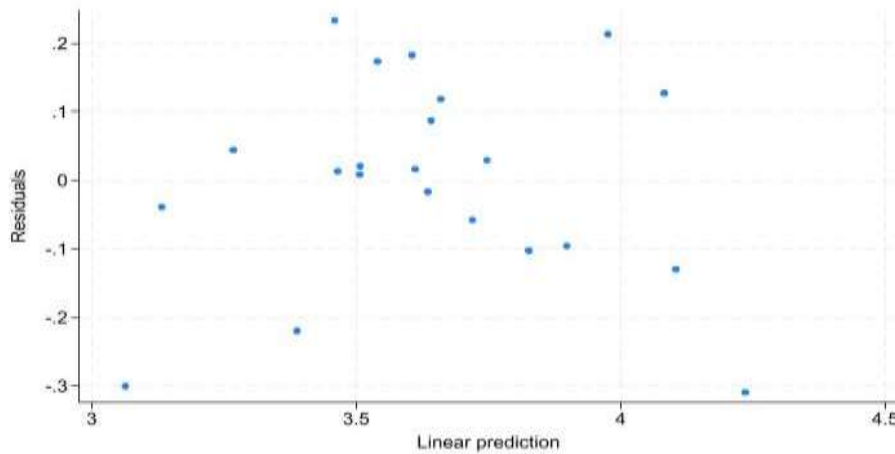
Partial regression plot (tariff rate and price)



The partial regression plot indicates that there is a weak positive relationship between TARIFFRATE i and \ln price as the fitted line is slightly upward sloping. The points are, however, quite

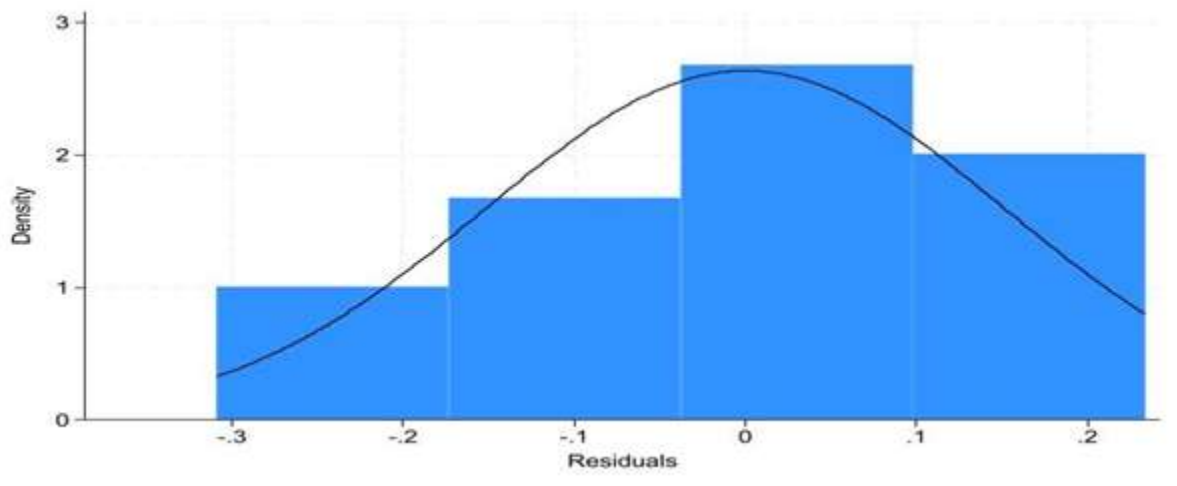
far apart indicating that there is a weak and incoherent association. This is in line with the regression findings, in which the tariff variable is not statistically significant.

Figure 5
Plot of residuals versus fitted values



As shown by the plot of residuals versus fitted values, the dispersion of points around zero is rather random, and there is no discernible pattern. This indicates that the model is fairly well specified, and that the linearity assumption is met. Moreover, heteroskedasticity cannot be considered very strong, since the dispersion of the residuals seems to remain relatively stable at the fitted values.

Figure 6
Residual histogram



The residual histogram indicates that the residuals are more-or-less normally distributed, with the shape having a general shape of a bell curve. Although there are minor variations in the perfect symmetry, the overall pattern does not show a significant deviation to normality. This helps in the assumption of the normal distribution of errors in the regression model.

Conclusion

This paper examines how tariffs and macroeconomic variables affect the prices of non-ferrous metals in the US using the multiple regression model. The results indicate that import demands are a major factor when it comes to setting metal prices, which suggests that market-driven forces are important. Prices are positively correlated with GDP, and it represents the impact of the overall economic activity. However, tariff rates are statistically significant, indicating that trade policy has a weak direct impact on the movements of metal prices. This can be attributed to the international character of the metal markets, where prices are more informed by international demand and supply factors rather than country specific policies. The diagnostic tests indicate that the model meets important assumptions, like homoskedasticity and no autocorrelation. Nonetheless, the Ramsey RESET test suggests the potential model misspecification, which means that a future study should consider adding more variables or other forms of the functions. The findings of the study suggests that tariffs should be seen as significant policy instruments; however, their immediate impact on the prices of metals is minor in comparison to such underlying economic processes as demand and economic development.

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Appendix

1. US NON FERROUS METAL PRICE DATA – 2003-2026

Table Data - Producer Price Index by Industry: Secondary Smelting, Refining, and Alloying of Nonferrous Metal (Except Copper and Aluminum): Primary Products | FRED | St. Louis Fed

2. Imports data

Table Data - Producer Price Index by Industry: Secondary Smelting, Refining, and Alloying of Nonferrous Metal (Except Copper and Aluminum): Primary Products | FRED | St. Louis Fed

3. US tariff data

United States - Tariff rate

4. Exchange rate – usd per SDR

Data Explorer

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