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Hedging geopolitical risk with industrial metals

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Dissertation written under the supervision of Professor Susana Campos Martins

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Abstract

The main purpose of the study "Hedging geopolitical risk with industrial metals" is to analyze whether industrial metals, particularly copper, aluminium, nickel and zinc, offer safe haven attributes or serve as reliable hedges against geopolitical risk. The research performs both daily and monthly regression analysis, applying the global common volatility (COVOL) index as a robust proxy for financial market risk. The results indicate that industrial metals are not appropriate hedging instruments during times of greater global uncertainty, as the results indicate a statistically significant negative relation with higher geopolitical risk.

Yet, the research highlights the pro-cyclical characteristics of industrial metals by finding positive correlations with macroeconomic factors like inflation and global manufacturing. These metals continue to be vital to the world economy, especially considering industrial electrification and the shift to green energy. By concentrating on an asset class that has received less attention within the scope of geopolitical instability, the study adds to existing literature and points out the long-term value of industrial metals as assets with economic relevance and benefits for portfolio diversification, rather than crisis hedges.

Keywords: Geopolitical risk, Industrial metals, Precious Metals, Safe haven, Hedging, COVOL

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Resumo

O principal objetivo do estudo “Hedging geopolitical risk with industrial metals” é analisar se os metais industriais, em particular o cobre, o alumínio, o níquel e o zinco, oferecem atributos de refúgio seguro ou servem de cobertura fiável contra o risco geopolítico. A investigação efetua uma análise de regressão diária e mensal, aplicando o índice de volatilidade comum global (COVOL) como um indicador robusto do risco do mercado financeiro. Os resultados indicam que os metais industriais não são adequados como ativos defensivos durante períodos de maior incerteza global, uma vez que apresentam uma relação negativa estatisticamente significativa com risco geopolítico mais elevado.

Contudo, o estudo salienta as caraterísticas pró-cíclicas dos metais industriais, encontrando correlações positivas com fatores macroeconómicos como a inflação e a produção mundial. Estes metais continuam a ser vitais para a economia mundial, especialmente no contexto da eletrificação industrial e da mudança para a energia verde. Ao concentrar-se numa classe de ativos que tem recebido menos atenção no âmbito da instabilidade geopolítica, o estudo contribui para a literatura existente e realça o valor a longo prazo dos metais industriais como ativos com relevância económica e benefícios para a diversificação de carteiras, e não como cobertura de risco durante crises.

Palavras-chave: Risco geopolítico, Metais industriais, Metais preciosos, Refúgio seguro, Cobertura, COVOL

Título: Cobertura do risco geopolítico com metais industriais

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Contents

Table of Figures

Table of Tables

Motivation

The ongoing energy transition is causing major shifts in global commodity markets, a transformation essential for reaching a net zero economy. The realization of such a transition will be greatly influenced by the future supply-demand dynamics of critical minerals like aluminium, copper, nickel, and zinc, which are necessary for the implementation of low-carbon technologies. Yet, supply chain resilience is at risk due to geoeconomic fragmentation and the growing enforcement of trade barriers despite mounting national security and geopolitical concerns, which raises fears concerning price volatility and market disruptions (Miller & Martínez, 2025).

This results in growing demand, irregular price fluctuations and shortages in the supply chain. On top of it, geopolitical concerns have caused critical minerals, including a variety of industrial metals, to climb up the policy agenda over the last few years, not least because of the current conflict between Russia and Ukraine and the growing tensions between the United States and China over the ongoing trade dispute. As those kinds of minerals are necessary for many of the quickly expanding energy technologies of the present time, ranging from electric cars and wind turbines to electrical networks, the need for them is rising rapidly as the energy transition picks up speed (Salinas, 2024).

The mineral resources employed depend on technology. Copper plays a major role as it serves as the foundation of technology of all kinds. Substantial volumes of aluminium are required for electricity networks and nickel is an essential component for the performance of batteries. Zinc is a widely available and inexpensive metal that is becoming increasingly popular as a potential battery technology substitute. For energy systems to remain secure in the coming years, a stable supply of critical minerals will become even more indispensable. Mineral markets are now at an unparalleled concentration level compared to other main commodities necessary for today's economy (International Energy Agency, 2024).

Due to their cyclical character and reliance on the macroeconomic environment, the four industrial metals are especially intriguing for this study since they combine market sensitivity with economic significance. Their dual role emphasizes how important it is to understand their behavior in light of geopolitical risk factors (Miller & Martínez, 2025). Although the safe-haven qualities of precious metals like gold and silver have been frequently studied in relation to geopolitical risk, such as by Baur and Smales (2020), though not much research has been done to quantify the value of industrial metals in such a setting.

The research question to be answered in the dissertation is whether there is any connection between the returns of industrial metals and geopolitical risk. More precisely, during times of geopolitical risk, is there any advantage in relying on industrial metals such as copper, aluminium, nickel, and zinc in comparison to assets that are believed to be safe havens, including gold, the US dollar or T-Bills of the US government?

Literature Review

Geopolitical risks such as terrorism and armed conflicts, political turmoil and changes in legislation, along with environmental and climate concerns are causing challenges to investors. Diversifying this risk is difficult because they are frequently systematic and have the potential to have a worldwide impact.[1] It is crucial for investors to understand how metals behave amid market crises given the historically low correlation between them and the stock and bond markets. For instance, in times when gold does not provide a safe haven, silver, platinum, and palladium might do. Plus, when they all serve as safe havens, precious metals can occasionally be more effective havens than gold. This enables precious metals to be instruments for risk management in times of financial and economic turmoil (Li and Lucey, 2014).

Accordingly, Gagnon et. al., 2020 have found evidence that commodities may provide a hedge against financial instability, demonstrating safe-haven attributes, with certain commodities indices greatly enhancing portfolio performance. This is similar to Chesney et. al., 2011, who have studied the impact of terrorism on financial markets and have discovered that investments in commodities are more advantageous than gold as the latter reacts more frequently in a negative way. Furthermore, the adverse effects on the price of gold are more persistent than those on the commodity market as a whole. Yet, the commodity market will likely respond negatively to some terrorist incidents in the near term, indicating that gold and commodities might not always be appropriate hedges.

Foglia et. al., (2023) have observed that countries are affected differently by geopolitical risk in relation to commodity markets. Thereby, the spread of geopolitical risk becomes increasingly noticeable across nations that are close to one another. The geopolitical relationships between

[1] Only research that explicitly relates to the connections between distinct geopolitical risk and commodities or other financial instruments will be reviewed in this part. The vast amount of research on the general topics of using commodities to hedge against inflation risk will therefore not be addressed.

states seem to have an impact on the dynamics of commodity prices. Therefore, the appropriateness of precious metals in the role of safe havens varies by market and asset type. Gold is the most consistent safe haven in the United Kingdom and Germany, especially in times of bear markets, while silver provides the greatest safe-haven qualities against decreases in stocks and bonds in the United States, followed by gold, palladium, and platinum (Li and Lucey, 2017).

Elder et. al., (2011) revealed that increases in actual economic activity, consumption, and investment have a negative impact on the price of gold and silver. Conversely, copper's performance is in line with its standing as a significant industrial metal that predominantly gains from unanticipated economic expansion. As such, news releases, which reveal an unanticipated strengthening of the economy typically have a favorable impact on copper prices but a negative effect on the prices of both gold and silver. Comparatively, economic news has an advantageous effect on realized volatility and volume for all three metals.

The various commodities' contributions to diversification range significantly from one another. As such, industrial metals, agriculture, and livestock are all helping to lower risk, while energy and precious metals serve to mitigate risk and simultaneously increase return. Furthermore, Belousova and Dorfleitner (2012) found out that in rising markets, investors barely gain from investing in industrial metals.

When taking a closer look at the price of gold, the main monetary factors that cause fluctuations are inflation, interest rates, and the expansion of the money supply, which further supports gold's function as a surrogate money. The price of silver is essentially untouched by either monetary or financial variables, which calls into question its supposed replacement for gold in portfolios. Conversely, platinum and palladium are impacted by the two and behave more like financial market assets (Batten et. al., 2009). Geopolitical actions have a detrimental impact on platinum, and it has been found that the majority of commodities' futures returns are negatively correlated with geopolitical risks. The justification for this is that commodity markets are impacted by geopolitics. A scarcity of supply and an increase in price result from events like trade wars, the closure of major transportation routes, conflicts, and societal upheaval that make it impossible to produce or transport a particular good (Mitsas et. al., 2022).

Opposite findings have been found by Parnes and Parnes (2025), which discovered that commodity indices and futures are consistently correlated with geopolitical risk. The authors also point out that commodities, such as natural gas, crude oil, copper, silver, and platinum may serve as safe havens, particularly during times of high volatility. Their study is comparable to

Baur and Smales (2020) who have shown that holding precious metals in a diversified portfolio can serve as a hedge against geopolitical risk. Their findings indicate that while precious metals might mitigate geopolitical risk to some extent, gold and silver seem to have this characteristic consistently across both moderate and severe geopolitical threats. Likewise, equities and bonds react adversely to geopolitical risk. However, there is a lack of research on how industrial metals react to changes in geopolitical risk, which this study aims to answer.

The Critical Role of Industrial Metals in the Global Economy

Fueled by the need to fight climate change, productive sectors are under pressure to make the reduction of their carbon footprint a top strategic priority. Minerals including copper, nickel, and zinc have become even more crucial to the world's economy as those minerals are essential components for the development of green technologies like renewable energy generation, energy storage, electric vehicle manufacturing or the construction of environmentally friendly buildings. Unsurprisingly, demand for such minerals is expected to increase, offering the mining and metals industry around the world a substantial opportunity for growth (Salinas, 2024).

This puts the sector under pressure to increase output to support this shift. Concerns regarding short-term supply constraints have diminished as a result of the significant expansion in the production of important energy transition minerals over the last few years. Alongside this

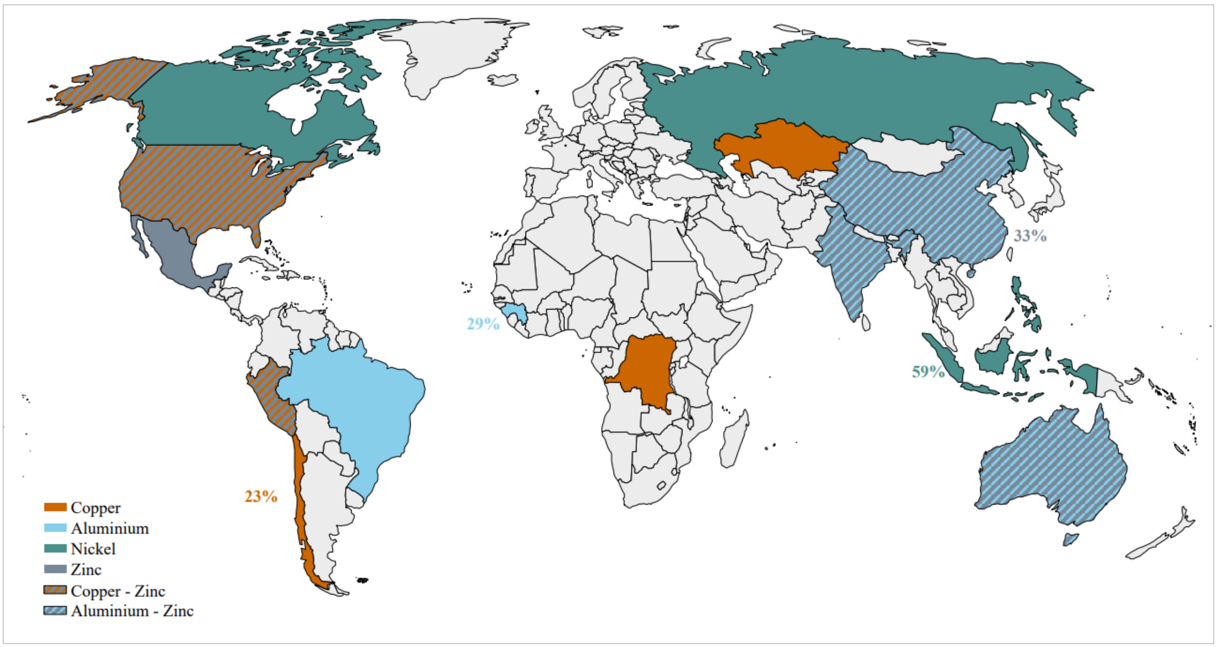


Figure 1: Location of major Industrial Metal Production

The countries having the highest mining output of each industrial metal are highlighted on this map. Each metal's main producing country and its equivalent global production share are indicated. Source: U.S. Department of the Interior (2025) expansion, there has been a rise in geographical concentration. Although the mining industry is notorious for having high levels of supply concentration, the problem has been made worse by additional production surges from the leading suppliers (International Energy Agency, 2024).

In light of their perceived wealth of particular natural resources, several countries – as shown in Figure 1 above – might even have direct control over the reserves, mining and refining and thereby the prices of particular commodities. As a result, significant geopolitical disturbances in or near certain countries can disrupt a variety of commodity markets both locally and globally (Dror Parnes, 2025).

In contrast to the geographical location of the mine, evaluating output by ownership (depending on the location of the headquarters of the owner) reveals a totally different picture. Despite the apparent geographical location of mines, corporations in the United States and Europe contribute significantly more to the supply of critical minerals than local mining companies of the reserve rich countries. A significant portion of this comes from some of the primary multinational mining corporations, like BHP, Rio Tinto or Freeport - McMoRan.

Mining companies are currently severely impacted by low prices, which are made worse by rising production costs. The biggest contributor of cost for copper and nickel were royalties, while the primary drivers for industrial materials overall were energy and reagent prices. Since today's leading suppliers usually operate at the bottom of the cost curve, this could result in even more regional concentration.

In recent years, capital expenditures by mining corporations for mines and processing facilities have grown, and more projects are being announced, which implies that supply quantities will increase in the years to come. Investing in the supply chain is important, but so is maximizing the potential for innovation, recycling, and behavioral change. In addition to reducing the amount of mineral demand, a strong concentration on recycling can provide significant security benefits for countries that rely on imported resources.

When it comes to the trading of industrial metals, reserves and trading volumes at the main metals futures markets serve as an indicator of liquidity. The long-standing industrial use of copper, aluminium, nickel and zinc has led to increased trading activity on the London Metal Exchange (LME), Shanghai Futures Exchange (SHFE), or Chicago Mercantile Exchange (CME), also being the reason used in this study (International Energy Agency, 2024).

The four industrial metals employed in the analysis will be addressed in the parts that follow, along with their global presence, supply and demand characteristics, and their crucial roles in influencing the global economy of today.

Copper

Given its unparalleled mix of qualities - electronic conductivity, longevity, ductility, and corrosion resistance - copper is the sole essential mineral found in all significant clean energy technologies, including electric vehicles, solar photovoltaic systems, wind, and electrical networks. For this reason, copper supply stability is crucial to the energy transition.

Construction and power networks have historically accounted for the majority of the world's demand for refined copper. Other significant demand sources are the transportation industry and the manufacturing industry. Going forward, the primary drivers of the demand growth are the substantial development of electrical networks and the rapid adoption of electric vehicles and renewable energy sources (International Energy Agency, 2024).

In comparison to the other important energy transition minerals, the supply of copper is relatively diversified. As illustrated in Figure 2 below, Chile is still the top copper miner, with around a fourth of the world's supply, followed by the Democratic Republic of Congo, doubling its stake to 14% over the last few years driven by its top-quality copper resources worldwide. Third ranks Peru with over 10% of total world production[2].

China on the other hand continues to dominate the copper refining industry. In 2024, mined copper supply remained stable with reductions in Chile and other countries offsetting considerable growth in the Democratic Republic of the Congo (DRC). The absence of major projects in the pipeline presents problems for the supply of copper in the foreseeable future (U.S. Department of the Interior, 2025).

Even though Chile produces the majority of the world's copper, European companies represent the largest share of ownership with around 20%, followed by companies from the United States. Currently, the top three producers almost control half of the market, which has remained consistent over the last ten years. The present project pipeline indicates that the supply of mined

[2] Unless otherwise stated, data on Industry production statistics was sourced, from the Global Critical Minerals Outlook 2024 published by the International Energy Agency, and the Mineral Commodity Summaries 2025 published by the U.S. Department of the Interior.

copper will reach its peak in 2026, after which it will begin to decrease as assets age and grades deteriorate (Jelmayer, 2024).

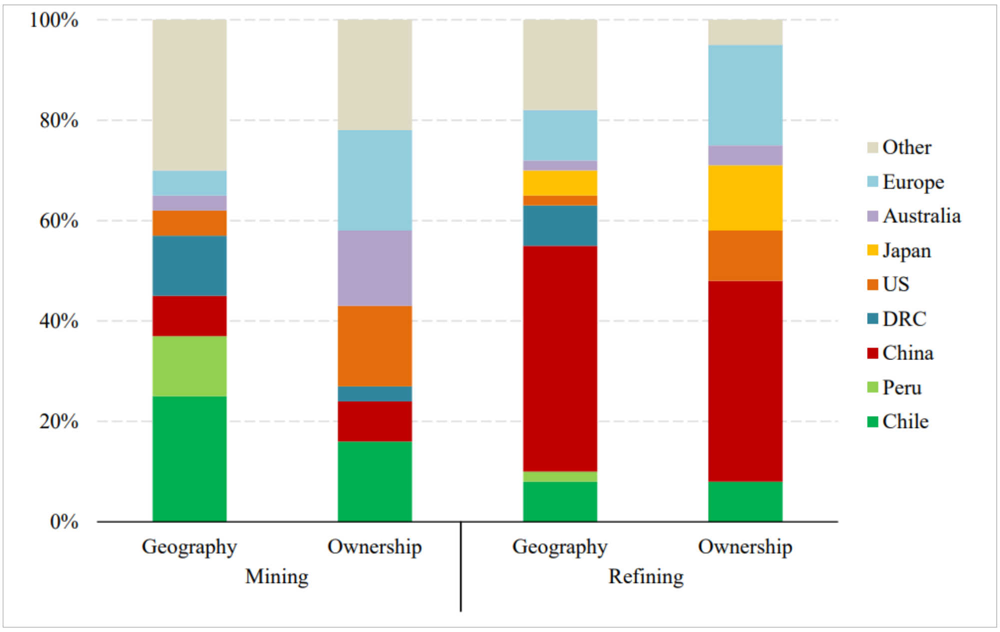


Figure 2: Copper mining and refining by geography vs. ownership, 2023

This figure shows the differences between geography and ownership of mining and refining of copper. Source: International Energy Agency (IEA) Global Critical Minerals Outlook 2024

Compared to mining, copper refining is considerably more concentrated, with the top three refinery countries in terms of geography and ownership currently being responsible for around 60%, with China alone having a 45% stake in both categories, followed by European companies with 10% geographically but double as much in terms of ownership. Third ranks Chile with 8% (refinery and ownership), implying that large volumes of the mined output are being exported for refining (International Energy Agency, 2024).

Copper's primary problem is a decreasing ore quality, resulting in deeper exploration and the requirement to extract more trash to sustain production levels, which raises operating and capital expenses. Apart from that, regional social and environmental obstacles, especially in Latin America, are another source of pressure (Salinas, 2025).

As Latin America is home to the majority of the world's largest mines, if any of these encounters significant opposition, causing logistical disruptions or shutdowns, the worldwide supply of copper may suffer significantly. Considering that four of the largest five mines in the world today are situated there, this emphasizes a particular vulnerability to the metal.

It is anticipated that from 2030 onwards, there will be a significant supply shortage of copper, mostly due to the sharp rise in demand caused by the use of clean energy technologies and the deteriorating quality of the ore found in the deposits. To mitigate the strain on primary copper supply needs, a variety of alternatives will be required to address the significant supply gap. This comprises significant corporate and governmental supply and demand initiatives, such as recycling, increased material efficiency, investment, and substitution (International Energy Agency, 2024).

Since the demand for copper is influenced by the general state of economic activity, any severe recession usually causes copper prices to drop drastically and any large increase in economic activity causes copper prices to rise significantly (Spurga, 2006). This pattern can be observed in the development of the metal's price in Figure 5 below.

Aluminium

As the second most widely used metal worldwide and the second naturally occurring metallic element, aluminium is essential to industrial and commercial output worldwide. The metals robust strength-to-weight ratio, durability against corrosion, and thermal conductivity have enhanced its standing as a material that can be used in a wide range of sectors and opened up countless technological possibilities (Harbor, The Aluminum Authority, 2025).

Aluminium is an essential component of many different industries, such as construction, transportation, electrical appliances, and other kinds of machinery and equipment. Furthermore, aluminium is a key component of many technologies that are believed to be fundamental for the carbon-neutral transformation, including major parts of wind generators, the structural components of solar photovoltaic panels, and the foundation of electric vehicles, among many others (International Energy Agency, 2024).

Aluminium is primarily made from bauxite, a mineral that is comparatively abundant in nature. The world's bauxite deposits are enough to sustain present production levels for the next century, guaranteeing supply stability over the long run. The mining of the bauxite mainly occurs in Guinea, Australia and China, with its production being similarly diversified. Bauxite, though, is not aluminium, and in order to produce the final metal, the ore must first be processed into alumina before it is transformed into aluminium. Of the worldwide aluminium production China holds the largest market share with 60%, followed by India and Russia (U.S. Department of the Interior, 2025).

The use of energy is a crucial part in producing aluminium, making up over 30% of the expenses and, subject to the type of electricity generation, it might also be a significant source of emissions. As a result, the site of new aluminium smelters has been mostly influenced by the cost of capital and the availability of cheap energy. These factors are responsible for the rise in output along with capacity in middle-income nations and the fall in production in more expensive regions like North America and Europe (Laing, 2023).

Therefore, a possible future scenario implies a rise in the demand for aluminium worldwide which will be driven by new modes of transportation (mainly electric vehicles), the construction industry, packaging, and electrical sectors, which are going to require 75% of the available metal (Jelena Aleksić, 2023). This demand would mostly be satisfied by a supply of aluminium from China or India that is particularly emissions intensive. This would make the supply chain more vulnerable to geopolitical tensions and leave a residue of emissions that could negate some of the benefits of moving to renewable energy (Laing, 2023).

Nickel

Nickel is utilized in many different fields, due to its exceptional physical and chemical characteristics—such as its extremely high melting point, resistance to oxidation and corrosion, and great ductility, which makes it crucial to the global economy. As such, it is employed for example in stainless steel, metal-based alloys, and EV batteries, which also represent the largest driver of future growth. Furthermore, nickel finds use in low-emission electricity production, including wind and geothermal energy (Nickel Institute, 2025).

On the supply side, Indonesia is assumed to continue the world's primary producer of mined ore and processed primary nickel goods, whereas China is expected to be the main supplier of sulfate. The demand for nickel worldwide has been increasing and the market may experience some surplus in the near future due to significant investment in nickel projects over previous years. Longer-term supply expectations from projects that have been announced might not be sufficient for fulfilling primary supply needs (International Energy Agency, 2024).

There has been a growing geographic concentration of the mined nickel industry, with Indonesia being the number one nickel mining country raising its share of world production to 60% in 2024. Indonesia is followed by the Philippines and Canada. The geographical concentration is expected to rise even further, with the share of the top three producing nations - Indonesia, the Philippines and Canada - increasing from 75% at present to 83% by 2040.

Like the mining of nickel, the output of refined nickel has grown dramatically in the past five years, which is mostly due to Indonesia's nearly fivefold jump in production. The leading three producers' – Indonesia, China, and Finland - concentration increased from 50% to 70%, while that of Indonesia alone, rose from 30% to 45% (U.S. Department of the Interior, 2025).

The current low-price poses concerns about the supply of nickel in the future as well as to chances for increased diversification. Although the sustained low nickel prices help the market for electric vehicles expand by maintaining low battery costs. A possible drawback is that this might result in more nickel mine shutdowns, which would further diminish supply diversity in an industry that is largely geographically concentrated (International Energy Agency, 2024).

Zinc

Zinc ranks fourth globally in terms of usage after iron, aluminium, and copper. Its main industrial application is the galvanizing process (60% of zinc use), which protects iron or steel from corrosion - making it last nine times longer. This is especially important in construction and transport infrastructure. Becoming even more important is the application for energy storage, as zinc-carbon batteries provide a higher energy density at a cheaper cost than other available cells (International Zinc Association, 2025).

Another huge beneficial characteristic of zinc is its 100% recyclability, meaning that its quality won't be degraded during recovery and reuse. Nowadays, recycled or secondary zinc contributes 30% of global zinc production (Venditti, 2022). This leads to huge environmental benefits, compared to primary zinc mining, as it comes to less resource depletion, water consumption, and land use (International Zinc Association, 2023).

Zinc is a naturally occurring metal with mineral deposits found all over the planet, meaning that there are enough reserves to satisfy demand for many years to come. Currently, there are around 50 countries that extract zinc ore, showcasing decentralized production. However, there are numerous nations making substantial contributions to its extraction, including China, being the world's leading producer of zinc. Other significant producers are Peru and Australia. Over half of the worldwide production comes from these three nations. In contrast to less diversified supply chains of other metals, this demonstrates a comparatively balanced and varied worldwide production landscape for zinc (U.S. Department of the Interior, 2025).

Due to the increasing demand for solar, offshore wind, and battery storage, zinc usage for renewable energy is expected to skyrocket by 2030. As such, it is expected that the demand for zinc used to produce batteries alone will increase from 300 tons in 2020 to 136,000 tons in 2030. Therefore, zinc is set to become a vital component of sustainable energy technology as the world moves toward a low-carbon economy (Venditti, 2022).

Data

Geopolitical Risk measure

The increasing importance of geopolitical risk and the necessity to quantify this type of risk have resulted in the development of several geopolitical risk indicators. One of the most prominent is the geopolitical risk (GPR) index by Caldara and Iacoviello (2022).

The index illustrates how text data is used to assess articles from newspapers and how asset prices respond to this data. The index offers a larger spectrum of geopolitical events. According to the authors, geopolitical risk is the potential threat of war, terrorism, and state-to-state tensions that interfere with the regular and peaceful flow of international interactions. This description involves the danger of these occurrences happening as well as the danger of an intensification of already-occurring events. The underlying assumption is that higher levels of geopolitical risk are the reason for an increase in news coverage.

As shown in Figure 3 below, the GPR Index spikes are mostly caused by two types of geopolitical occurrences: more general, military conflict-led events like the second Gulf War, the Syrian Civil War, the 2022 Russian invasion of Ukraine, and the Israel - Hamas War, and more acute, terrorism-related incidents like 9/11, the London bombings, and the 2015 Paris attacks.

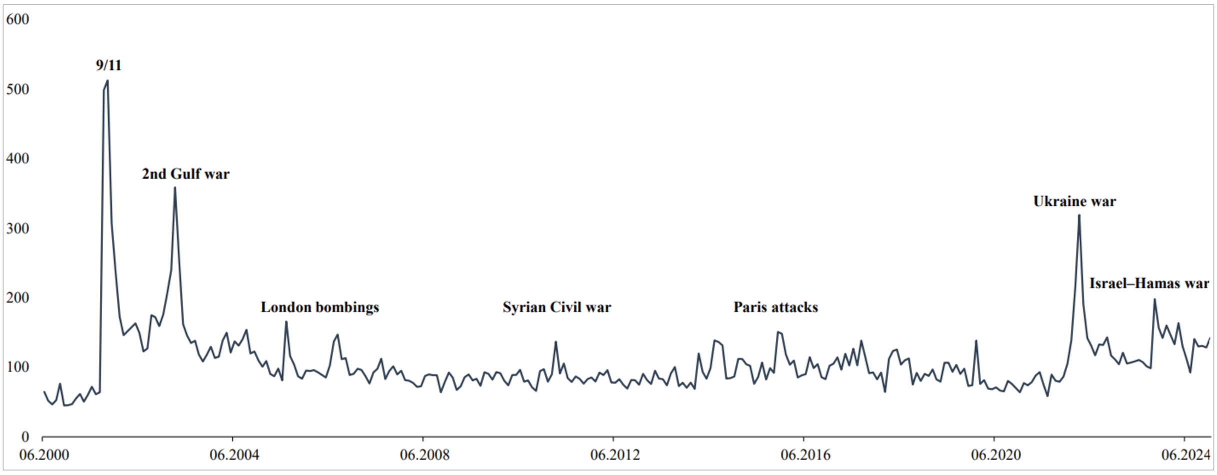


Figure 3: Geopolitical Risk (GPR) Index

This figure plots the GPR Index over the period 2000 - 2024. Source: "Measuring Geopolitical Risk" by Dario Caldara and Matteo Iacoviello at https://www.matteoiacoviello.com/gpr.htm

In this study, the index mainly applied will be global common volatility (COVOL) by Engle and Campos Martins (2022), a comprehensive indicator of all forms related to global financial risk. Global COVOL is an extensive risk indicator that reflects how significantly global events have impacted the value of assets in different geographic regions and asset types throughout the last decades. It shows the magnitude of such events and their effect on financial markets. The history of the index over the sample period is illustrated in Figure 4 below.

In the study, COVOL is subtracted by "1" so that "0" becomes the neutral risk point. In the figure below, values above 0 indicate elevated geopolitical risk, and values below 0 indicate periods of relative stability.

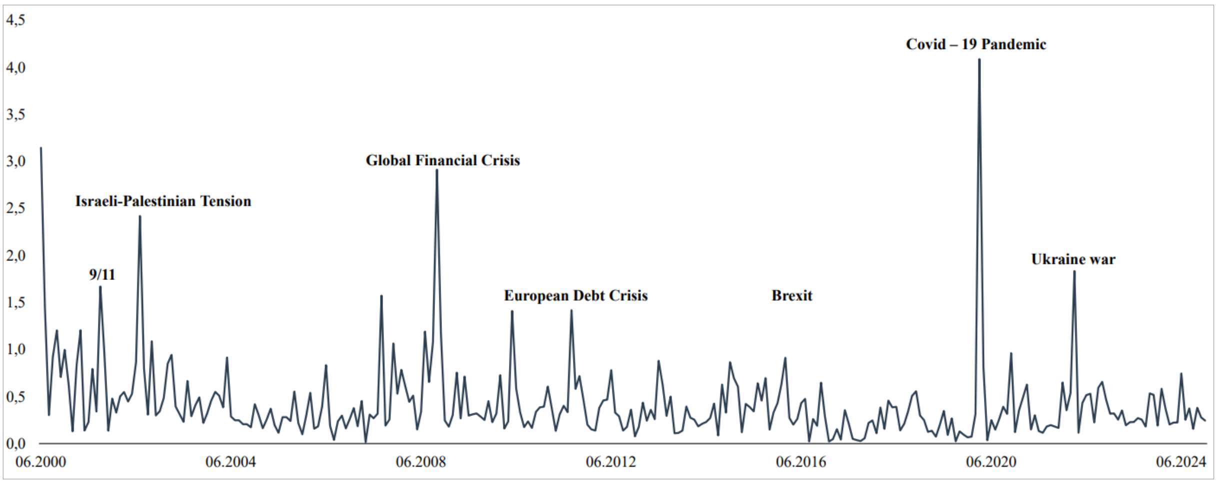


Figure 4: Global Common Volatility (COVOL) Index

This graph plots the monthly global COVOL Index (here as $COVOL^2$) over the period 2000 – 2024. Source: "What are the events that shake our world? Measuring and hedging global COVOL" by Robert F. Engle and Susana Campos-Martins (2022)

The index shows a number of notable spikes that match important world events. The COVID-19 pandemic in the beginning of 2020 marks the highest peak, with the Israeli – Palestinian Tensions in 2002, and the 2001 9/11 terrorist attacks following with considerable rises. The Global Financial Crisis, the European Debt Crisis in 2010 – 2012, and the 2022 Russian invasion of Ukraine are some notable instances of global volatility.

COVOL acknowledges that assets from different types of asset classes, industries, or countries, react differently to impactful news. COVOL is a reliable indicator that records significant global risks instantaneously as they are viewed by the public, media, investors, and policymakers. Additionally, COVOL incorporates occurrences that aren't usually clearly categorized as geopolitical. Since they frequently result from and are caused by a wide range of factors and effects, these could include climate change, significant democratic political events (like Brexit), and worldwide recessions (like the global financial crisis).

In contrast to geopolitical risk (GPR), global COVOL provides a more comprehensive understanding of market risk resulting from various shocks across regions and asset classes by assessing the total effect of significant global events on asset prices. For comparative purposes, the later part of the empirical anylysis will include a regression applying the GPR time-series, transformed by taking the natural log of the GPR index (+1) and and then calculate first differences. The data mismatch is given by the fact that the news captured by the index are being published only one day later, resulting in a delay of the GPR index. By lagging the data one day backwards, it can be ensured, that the data of the key explanatory variable is alligned with the daily metal returns. Lastly, a regression with both geopolitical risk indicators and no control variables will be conducted to quantify which of the two measures has a higher explanatory power.

Returns

The key objective of this study is to understand how industrial metal prices react to shifts in geopolitical risk. Given their unique supply and demand patterns, the four industrial metals are attractive to investigate since they could react differently to risk variables like global COVOL. The price of a metal mined in a country with a higher geopolitical risk is probably going to react differently to shifts in that risk than metals extracted in a country with a more stable geopolitical environment.

The daily settlement prices for copper, aluminium, nickel, and zinc are obtained from Refinitiv Workspace Datastream in the period of 01.06.2000 until 31.12.2024. All four industrial metals are priced in USD per metric ton. The precious metals, including gold, silver, palladium and platinum, as analyzed by Baur and Smales (2020) are also analyzed for comparison. The closing prices on day t (P_t) and t-1 (P_t-1) are then used to compute the daily returns for day t, R_t:

$$R_t = 100 * \ln (P_t / P_{t-1})$$

Figure 5 below shows how market prices of the four industrial metals as well as the MSCI World have performed over the analyzed time frame. Among the four industrial metals, copper has shown the best long-term price performance, despite suffering steep declines during significant world crises like the COVID-19 epidemic and the 2008 financial crisis. In contrast, nickel has the most volatile pricing patterns, especially in recent years, with notable price increases at occasions like as the conflict between Russia and Ukraine.

The price movements of aluminium and zinc were more moderate but still clearly cyclical, closely following the state of the world economy. Despite being influenced by extreme geopolitical risk events like the 2008 crisis and the pandemic, the MSCI World Index has consistently increased, demonstrating the comparatively robust nature of international equities markets.

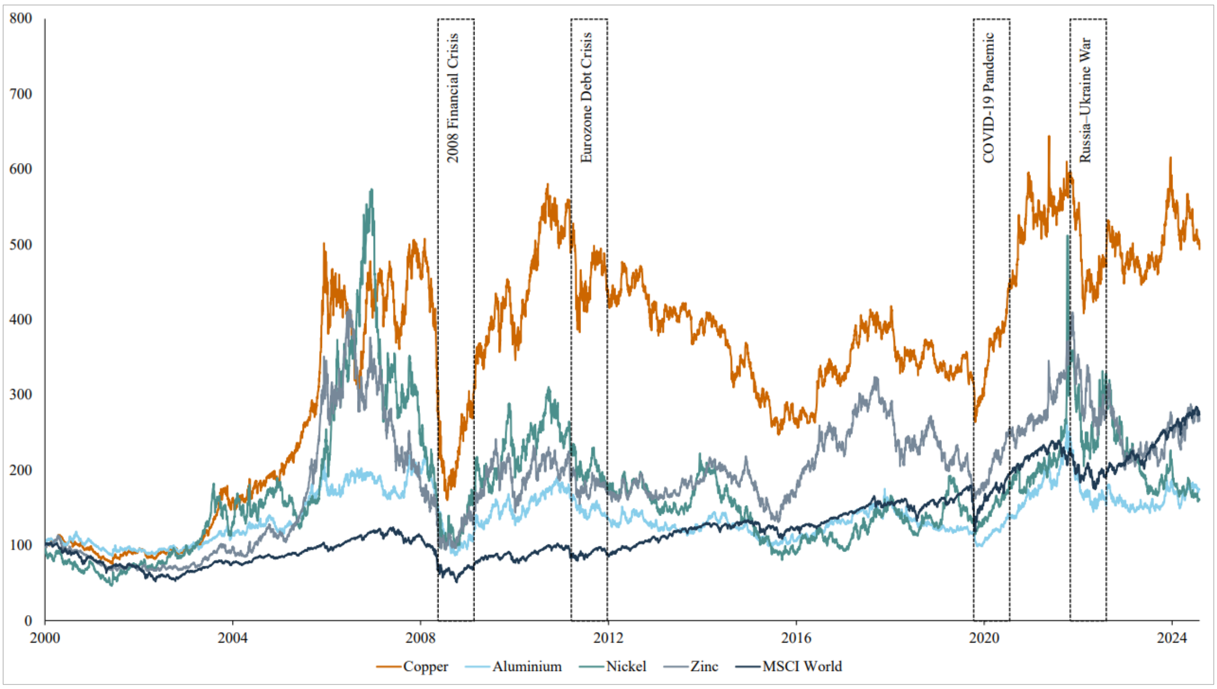


Figure 5: Industrial Metals Price Development

This graph depicts the history of the analyzed industrial metals and the MSCI World over the period June 2000 – December 2024. Prices are rebased to 100 as of June 2000. Daily data

These trends imply that copper prices typically fall drastically during times of severe geopolitical and macroeconomic stress more than those of other industrial metals - underscoring their greater vulnerability. The volatility of nickel and zinc, on the other hand, is quite moderate compared to copper and seems to respond particularly to shifts in supply and demand, whilst aluminium exhibits the lowest volatility and more consistency across crisis moments. The development of the market prices of the precious metals can be seen in Appendix B.

Table 1 below shows the descriptive statistics for COVOL (here $COVOL^2 - 1$), the four industrial metals (copper, aluminium, nickel, and zinc), and for comparative purposes also the precious metals (gold, silver, palladium and platinum). COVOL has a significant degree of positive skewness (5.14), a standard deviation of 0.545, and a very high kurtosis (47.38), showing an extreme but occasional spike distribution that is in line with the characteristics of geopolitical risk shocks. Among the four industrial metals, copper had the highest average daily return (0.025%) over the course of the research period, followed by zinc (0.015%), aluminium

(0.009%), and nickel (0.007%). Yet, when it came to return volatility, aluminium was the most consistent of the four industrial metals (standard deviation: 1.370), while nickel had the highest deviation from the mean (2.347), indicating significant daily variations.

Table 1
Summary Statistics

	Contract Code	Mean	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis	Unit Root*
COVOL² - 1	CV2	-0.545	0.545	-1.00	7.23	5.14	47.38	-13.87 *
ΔGPR	ΔGPR	-0.000	0.378	-2.90	2.29	0.08	4.86	-27.03 *
Copper	HG	0.025	1.579	-10.36	11.73	-0.13	7.52	-16.86 *
Aluminium	AL	0.009	1.370	-8.26	6.40	-0.12	5.43	-18.56 *
Nickel	NI	0.007	2.347	-18.36	48.73	1.25	35.23	-18.83 *
Zinc	ZN	0.015	1.808	-11.47	9.95	-0.15	5.68	-18.90 *
Gold	GC	0.035	1.037	-10.16	6.87	-0.42	8.76	-18.92 *
Silver	SI	0.027	1.856	-17.37	13.86	-0.92	11.44	-18.81 *
Palladium	PA	0.007	2.201	-17.86	16.96	-0.41	9.12	-18.87 *
Platinum	PL	0.008	1.482	-17.28	9.34	-0.60	10.58	-17.64 *

* ADF test statistic with $p < 0.05$ indicating rejection of the unit root null hypothesis

Table 1: Summary Statistics

Information on the variables of interest used in this study. This includes the global common volatility (COVOL² - 1) index, the first logged difference in the geopolitical risk index, in addition to the daily returns of the four industrial metals analyzed (copper, aluminium, nickel and zinc), and for comparison a set of precious metals (gold, silver, palladium and platinum). The table includes the unit root test, calculated using the Augmented Dickey Fuller (ADF) test with trend and intercept and * showing the rejection of the null of a unit root at the 5% level. Sample Period: June 2000 - December 2024

In comparison, gold has the highest average return among all four precious metals (0.035), coupled with comparatively low volatility (standard deviation: 1.037). This reinforces its standing as a reliable store of value in a turbulent market environment. Silver demonstrates the largest negative skewness (–0.92) and a high volatility of 1.856, showing sporadic steep drops. Among the four precious metals, palladium showcases the highest volatility (2.201) and the lowest mean return (0.007). Platinum exhibits comparable distribution patterns although it has a little lower volatility (1.482).

According to the skewness and kurtosis values, the majority of return distributions are leptokurtic and express varying degrees of asymmetry, suggesting the existence of fat tails and a higher probability of abnormal return observations - a known feature of financial time series.

In particular, the periods of crises like the 2008 financial crisis coincided with the biggest negative returns across all assets, underscoring the industrial metal markets' responsiveness to shocks globally. For every return series, the unit root tests, applying Augmented Dickey-Fuller (ADF) demonstrate stationarity by rejecting the null hypothesis of a unit root at the 5% level.

Table 2 displays the correlation coefficients between the industrial metals, precious metals, and geopolitical risk as measured by COVOL or GPR. According to the table results, there is a tendency for the returns of the four industrial metals—copper, aluminium, nickel, and zinc—to decrease slightly during times of increased geopolitical risk. These correlations are low but statistically significant. Contrarily, there is not an obvious connection between most of the precious metals and geopolitical risk, suggesting a more idiosyncratic or neutral reaction. At the 5% level, only platinum presents a slight negative relationship (-0.032), whilst at the 10% level, gold (-0.021) and silver (-0.024) reveals a comparably small connection.

Table 2
Correlation Matrix: Industrial - Precious Metals

	$COVOL^2 - 1$	ΔGPR	Copper	Aluminium	Nickel	Zinc	Gold	Silver	Palladium	Platinum
$COVOL^2 - 1$	**1.000**	-0.002	**-0.050**	**-0.039**	**-0.038**	**-0.040**	*-0.021*	*-0.024*	-0.012	**-0.032**
ΔGPR		**1.000**	0.009	0.005	0.007	-0.007	**0.040**	0.004	0.010	0.009
Copper			**1.000**	**0.643**	**0.532**	**0.690**	**0.284**	**0.380**	**0.268**	**0.274**
Aluminium				**1.000**	**0.442**	**0.589**	**0.230**	**0.304**	**0.247**	**0.233**
Nickel					**1.000**	**0.501**	**0.191**	**0.262**	**0.194**	**0.201**
Zinc						**1.000**	**0.247**	**0.317**	**0.253**	**0.237**
Gold							**1.000**	**0.581**	**0.320**	**0.429**
Silver								**1.000**	**0.277**	**0.342**
Palladium									**1.000**	**0.575**
Platinum										**1.000**

Bold font indicates significant at the 5% level and italic font indicates significant at 10% level.

Table 2: Correlation Matrix Industrial - Precious Metals

Correlations between the different metals and $COVOL^2 - 1$.

Significant positive correlations have been identified between industrial metals within the metal groups, particularly between copper and zinc (0.690) and copper and aluminium (0.643), indicating that these metals are all exposed to global economic cycles. Precious metals also exhibit considerable internal co-movement, while gold and silver show the strongest correlation (0.581), being followed by palladium and platinum (0.575). These trends demonstrate the precious metal group's coherent behavior, but its weak associations with geopolitical risk point to little direct exposure to such events.

The correlation statistics provide interesting insights. First, there is a positive correlation between all metal returns, which is in line with the co-movement approach. Second, industrial metals are more likely to move stronger with themselves than with precious metals, and the other way around. The results are consistent with Agyei-Ampomah et. al., 2013 who also found that the co-movement amongst metals is greater in periods of crisis.

Financial and Macroeconomic state control variables

For the daily regression analysis, financial indicators are used as control variables. Firstly, the broad equity index MSCI World, which includes more than 1300 large and mid-cap stocks across 23 developed countries. The index has a strong weight on the US (72%), followed by Japan (5%) and the UK (4%). The US Dollar Index (DXY) represents the strength of the currency in which both the industrial and precious metals are priced. The index measures the performance of the US Dollar against a basket of other major currencies. Lastly, the risk-free rate, retrieved from the Fama and French website is included as well.

To provide a more comprehensive perspective, the study makes use of several recognized macroeconomic factors, where data is only available monthly, to control for the current state of the economy. First, Inflation is controlled through the Consumer Price Index for all Urban Consumer (CPI – U), obtained from the U.S. Bureau of Labor Statistics, representing the average change in prices over a given period for a basket of goods and services that urban consumers pay (U.S. Bureau of Labor Statistics, 2025). The Investor Sentiment is captured by the AAII Investor Sentiment Survey, which provides information on individual investors' perspectives by asking them about their expectations for the market's direction over the following six months (American Association of Individual Investors, 2025).

Global Manufacturing is measured through the OECD Total Production Index (excl. Construction). Industrial production comprises industries including mining, manufacturing, and energy and is defined as the output of industrial facilities (Organisation for Economic Co-operation and Development, 2025). A similar index captures solely the Chinese economy as the largest consumer of industrial metals by controlling for the Chinese Industrial Production Index, sourced from the National Bureau of Statistics of China.

Comparative studies have also taken into account the credit spread, term premium, volume and open interest. They have been intentionally omitted in the study as they have not shown any significance to the regression results.

Panel A of Table 3 below presents the correlation matrix for the financial control variables used in the daily regression analysis. The USD Index (0.027) and the risk-free rate (0.059) have a weak but positive correlation with COVOL, according to the data, with both of them being statistically significant at the 5% level. Although there is no clear connection between the MSCI World and COVOL or the other control variables, it does have a negative correlation (-0.263) with the USD Index, which is consistent of normal market dynamics. In general, the modest correlations between the controls minimize suspicions about the regression models multicollinearity.

The correlation matrix between macroeconomic indicators and COVOL is shown in Panel B of Table 3. COVOL and Global manufacturing have a notable negative relationship (-0.232), according to the results, implying that declines in global industrial production typically occur at the same time as rises in geopolitical risk. Furthermore, there is a positive and considerable correlation (0.294) between inflation and global manufacturing, indicating that inflation tends to increase in tandem with global output. There is a limited short-term direct co-movement with geopolitical risk and the remaining macroeconomic control variables. Appendix C illustrates a similar correlation matrix with ΔGPR as the key explanatory variable.

Table 3

Panel A: Correlation Matrix Control Variables - Daily

	$COVOL^2$ - 1	MSCI World	USD Index	Risk free
$COVOL^2$ - 1	1.000	-0.006	**0.027**	**0.059**
MSCI World		1.000	**-0.263**	-0.008
USD Index			1.000	-0.007
Risk free				1.000

Panel B: Correlation Matrix Control Variables - Monthly

	$COVOL^2$ - 1	Inflation	Investor Sentiment	Global Manufacturing	China Indus. Production
$COVOL^2$ - 1	1.000	**-0.165**	-0.042	**-0.232**	0.071
Inflation		1.000	0.045	**0.294**	0.008
Investor Sentiment			1.000	**0.145**	-0.082
Global Manufacturing				1.000	*-0.109*
China Indus. Production					1.000

Bold font indicates significant at the 5% level and italic font indicates significant at 10% level.

Table 3: Correlation Matrix Control Variables

Correlation between $COVOL^2$ - 1 and the control variables. Panel A with the financial variables used in the daily regression and Panel B with the macroeconomic variables used in the monthly regression

Empirical Analysis

Methodology

The effects of geopolitical risk on industrial metals will be examined using the following regression:

$$(1)\ R_t = ß_0 + ß_1 COVOL^2 - 1 + \varepsilon_t \text{ and}$$

$$(2)\ R_t = ß_0 + ß_1 COVOL^2 - 1 + ß_2 M_t + \varepsilon_t$$

Where:

R_t denotes the daily log return of the particular industrial metal (copper, aluminium, nickel, zinc) or one of the precious metals (gold, silver, palladium and platinum).

The key explanatory variable is COVOL the global common volatility measure, which acts as a thorough indicator of worldwide financial risk, identifying systemic shocks that raise volatility across various asset classes and geographical areas at the same time. COVOL is being subtracted by 1 so that "0" becomes the neutral risk point. Values above 0 indicate elevated geopolitical risk, and values below 0 indicate periods of relative stability.

M_t represents financial control variables in the daily regression, including the MSCI World for representing global equity markets, the USD Index and the risk-free rate (from Fama and French website). In the monthly regression M_t stands for macroeconomic control variables including inflation being measured by the consumer price index for all urban consumers (CPI-U), Investor Sentiment, captured by the AAII Investor Sentiment Survey, Global manufacturing to seize the output of worldwide industrial production and lastly the Chinese Industrial Production to control particularly for the output from China as the economy with the largest industrial demand worldwide. ε_t is the error term.

To examine how markets react to shifts in geopolitical risks, an altered approach tailored to the context of geopolitical risk is based on Baur and McDermott's (2010) terminology for hedge and safe haven. Where "hedge" is considered a (financial) asset serving as a strong (weak) hedge against geopolitical risk if the returns are positively correlated (uncorrelated) with fluctuations in geopolitical risk. A (financial) asset is considered a strong (weak) "safe haven", if the returns of the asset are positively correlated (uncorrelated) with fluctuations in geopolitical risk in times of extreme geopolitical risk.

It is essential for investors to distinguish between strong and weak hedges or safe havens, given that positive correlation suggests favorable returns for investors during periods of increased geopolitical risk (Baur and McDermott's, 2010). The regressions above test for the hedging characteristics based on the assumption that the correlation between an asset's return and variations in COVOL remains constant throughout a range of geopolitical risk levels.

Regression Results – Daily

Below in Panel A of Table 4 are the results for the regression generated with daily data. The first column of each industrial metal (1) shows the results of the baseline regression and the second column (2) the regression results with the three control variables.

Table 4
Regression (Daily): relationship between geopolitical risk ($COVOL^2$ - 1) and metal returns
Panel A: Industrial Metals

	Copper		Aluminium		Nickel		Zinc	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	-0.053 (0.028)	-0.058 (0.030)	-0.044 (0.024)	-0.045 (0.028)	-0.083* (0.041)	-0.068 (0.048)	-0.057 (0.032)	-0.046 (0.036)
$COVOL^2$ - 1	-0.144*** (0.036)	-0.125*** (0.033)	-0.098** (0.031)	-0.084** (0.030)	-0.165** (0.054)	-0.147** (0.052)	-0.132** (0.041)	-0.114** (0.039)
MSCI World		0.540*** (0.018)		0.339*** (0.017)		0.540*** (0.029)		0.476*** (0.022)
USD Index		-0.578*** (0.039)		-0.463*** (0.035)		-0.467*** (0.061)		-0.497*** (0.046)
Risk free		0.990 (2.359)		0.437 (2.136)		-1.924 (3.731)		-1.158 (2.824)
Adj. R^2	0.002	0.184	0.001	0.111	0.001	0.076	0.001	0.107
F-Statistic	15.784	361.370	9.765	200.659	9.456	132.254	10.140	194.027
DW Statistic	2.127	2.164	2.045	2.090	1.947	1.959	2.027	2.069
No. Obs.	6412	6412	6412	6412	6412	6412	6412	6412

Panel B: Precious Metals

	Gold		Silver		Palladium		Platinum	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.014 (0.018)	0.010 (0.021)	-0.017 (0.033)	-0.010 (0.036)	-0.019 (0.039)	0.006 (0.045)	-0.039 (0.026)	-0.043 (0.030)
$COVOL^2$ - 1	-0.039 (0.024)	-0.023 (0.022)	-0.081 (0.043)	-0.046 (0.038)	-0.047 (0.050)	-0.026 (0.049)	-0.086* (0.034)	-0.073* (0.033)
MSCI World		-0.005 (0.012)		0.307*** (0.021)		0.421*** (0.027)		0.275*** (0.018)
USD Index		-0.755*** (0.026)		-1.395*** (0.045)		-0.555*** (0.058)		-0.471*** (0.039)
Risk free		1.910 (1.608)		1.130 (2.763)		-3.021 (3.521)		0.997 (2.358)
Adj. R^2	0.000	0.121	0.000	0.189	-0.000	0.064	0.001	0.074
F-Statistic	2.708	221.526	3.665	374.951	0.860	110.204	6.436	128.638
DW Statistic	2.020	2.115	2.011	2.055	1.919	1.996	1.947	2.047
No. Obs.	6412	6412	6412	6412	6412	6412	6412	6412

Table 4: Regression (Daily): relationship between geopolitical risk ($COVOL^2$ - 1) and metal returns

This table shows the coefficients estimated using equations (1) and (2) as outlined above, where the dependent variable is the daily return on an industrial metal in Panel A and a precious metal in Panel B. Standard errors are reported in parentheses. ***, ** , and * indicate statistical significance at the 1%, 5%, and 10% level respectively. Sample Period: June 2000 - December 2024.

Looking at Panel A, the results indicate that for copper, aluminium, nickel, and zinc, the relationship between metal returns and geopolitical risk (as measured by $COVOL^2 - 1$) is negative and statistically significant. This means that rises (falls) in geopolitical risk are associated with decreases (increases) in industrial metal returns. For instance, a one-unit increase in COVOL corresponds to a 0.145 percentage point decrease in copper returns, in contrast to the 0.025% mean daily return. Likewise, with a one-unit rise in COVOL, returns for aluminium, nickel, and zinc fall by 0.099, 0.169, and 0.130 percentage points, respectively.

These findings suggest that industrial metals tend to decline during times of increased global common volatility (as also has been illustrated in Figure 4) rather than serving as efficient hedges against growing geopolitical risks as they consistently react negatively to growing global instability, which is apparent in this pro-cyclical behavior.

When adding the control variables in the second regression (2) - the MSCI World, USD Index and the risk-free - the negative relation between COVOL and industrial metal returns is still statistically significant for all metals. Adding control variables slightly reduces the effect of COVOL on returns for industrial metals, but the regressions predictive power is significantly increased, for example, adjusted R^2 for copper, aluminium, and zinc rises from almost zero in the baseline model to 0.185, 0.111, and 0.108, respectively. The MSCI World Index's coefficients are positive and highly significant at the 1% level (***), suggesting that the returns on industrial metals move in the same direction of larger equity markets though with smaller magnitude. Even so, the USD Index's negative coefficients imply that metals often do poorly when the US dollar gains value. Given that commodities are traded in US dollars, a stronger dollar raises the cost for non-dollar buyers, weakening demand and thereby resulting in lower prices and negative returns.

For comparison, the findings of the regression obtained from daily data for precious metals, in the baseline model (1), are shown above in Panel B of Table 4. Among the four precious metals, solely platinum reveals a negative but statistically significant relationship at the 10% level (*). A one unit increase in COVOL results in a 0.086 percentage points decline in the daily return of platinum. For the other three precious metals, the results signal a negative statistically insignificant relationship between returns to precious metals and geopolitical risk (as measured by $COVOL^2 - 1$) for gold, silver, and palladium. These results imply that, in contrast to industrial metals, precious metals only show a slight and statistically insignificant responsiveness to shifts in the global common volatility, implying that they might hold their value in the face of geopolitical upheavals.

After including the three control variables in regression (2), the results remain similar. Platinum, at the 10% level, presents a negative and statistically significant connection, with its returns decreasing by 0.072 percentage points for every unit increase in COVOL. Like the previous regression results, the models' explanatory power also greatly improves by including control variables, as evidenced by the rising adjusted R^2 values, especially for gold and silver, improving to 0.122 and 0.190 respectively.

In both panels, strong statistical significance can be seen for the MSCI World and the USD Index at the 1% level (***). It appears that metal returns, especially those of industrial metals, are sensitive to investor sentiment and economic conditions worldwide, as evidenced by their tight relationship to the direction of the equity market as overall. The strong significance is also reasonable given that commodities are dollar-denominated and highlight the strong negative link between metal prices and the US Dollar. This can be explained by the fact that the purchasing power of international buyers decreases with a strengthening currency. Moreover, the coefficients of the risk-free rate are insignificant in both metal groups and have substantial standard errors, indicating that short-term interest rate fluctuations do not have a direct impact on daily metal returns.

Unlike the results of Baur and Smales (2020), which have used the GPR index in their study, in this study precious metals do not reliably hedge against rises in global common volatility (COVOL), regardless of their exposure to equity market and currency changes. In fact, Baur and Smales (2020) results are opposite to the ones shown in Panel B, as they have found statistical significance for gold, silver, and palladium, though not significant for platinum, suggesting that those three precious metals are solid hedges against increased geopolitical tensions and conflicts.

The outcomes reaffirm the major disparity between industrial and precious metals in times of global instability. Precious metals, especially gold and silver, respond more gently to increasing global volatility than industrial metals, which is not surprising given their historical status as safe-haven investments. Also, the findings reinforce the expectation that industrial metals showcase pro-cyclical behavior, making them riskier investments, and even precious metals could be impacted to some extent by overall market conditions. Furthermore, a negative correlation with the USD Index indicates that currency fluctuations have an impact on metal returns, despite interest rates seeming to have a smaller short-term impact.

Regression Results – Monthly

In this section, monthly data is considered to control for macroeconomic variables such as Inflation (CPI-U), Investor Sentiment (AAII Investor Sentiment Survey), Global Manufacturing (OECD Total production Index) and the Chinese Industrial Output. Panel A of Table 5 below presents the regression results for industrial metals of the baseline model in column (1) and in column (2) the regression results including the control variables.

The results of the baseline model (1) with the monthly data are comparable with the daily data, illustrating also a negative relationship of all four industrial metals with COVOL. Though, in this case, only the coefficients for copper, nickel and zinc are statistically significant and in the case of copper not as strongly (10% (*)).

When adding the control variables in regression (2), the relation between COVOL and industrial metal returns continues to be negative for all metals but only statistically significant for nickel at 10% (*). The reduction in statistical significance is possibly caused by the lower frequency and loss of variation as well as a flattening of volatility effects since short-term responses to geopolitical shocks may be diluted by monthly averaging. The predictive ability of the regressions continues to be considerably improved by the addition of sentiment and macroeconomic factors, especially for copper and aluminium - the adjusted R^2 rises from almost zero to 0.146 and 0.088, respectively. Though, the values of adjusted R^2 remain slightly lower than in the daily regression.

When looking at the control variables, inflation demonstrates a substantial and significant positive influence on the returns of all industrial metals. This is probably because these metals are essential inputs of industries that are extremely vulnerable to cost increases, such as manufacturing, infrastructure, and construction. Also, during times of inflation, businesses may store industrial metals, which would raise prices.

Global manufacturing illustrates an interesting picture being strongly significant at the 1% (***) level for copper, 5% (**) for aluminium and not statistically significant in the case of nickel and zinc. The higher direct exposure to worldwide industrial activity might be an explanation for the greater relevance of global manufacturing for copper and aluminium, while more distinctive characteristics may account for the lower significance of global manufacturing in the case of nickel and zinc.

No statistical significance can be seen for investor sentiment and opposed to global manufacturing also not for Chinese industrial production across all four metals. The result of the latter might be affected by a lack of transparency, smoothing and interference by the Chinese government. These results imply that while monthly industrial metal returns cannot be adequately explained by geopolitical volatility alone, global manufacturing cycles and inflation pressures are important factors that influence metal price movements.

Panel B of Table 5 shows the baseline regression results for monthly data for the four precious metals. Notably, statistical significance can be seen for silver (*), palladium (**) and platinum

(***). This result might be because palladium and platinum are more niche metals and offer less liquidity than other metals such as gold. Their responses to geopolitical uncertainty might therefore be more gradual, cumulative, and apparent over longer time periods.

A comparable result is exhibited by the second regression including control variables. Noteworthy here are strong rises in the value of the adjusted R^2 of silver and platinum to 0.061 and 0.149 respectively. Across all four precious metals, inflation also demonstrates a statistically significant and continuously strong positive connection. This result is in line with broad knowledge that inflation is beneficial for precious metal returns. Global manufacturing is only significant for platinum, suggesting that the return of platinum is the most impacted by industrial activity of the precious metals group. Investor sentiment and the Industrial Production of China continue to be irrelevant also for precious metals. Given that industrial and precious metals are primarily influenced by underlying economic factors rather than changes in investor attitude, investor sentiment seems to be immaterial for both metal groups. Precious metals such as gold are frequently kept for long-term, strategic hedging instead of speculation, whereas industrial metals react mainly to actual economic activity and supply-demand patterns.

Table 5
Regression (Monthly): relationship between geopolitical risk (COVOL² - 1) and metal returns
Panel A: Industrial Metals

	Copper		Aluminium		Nickel		Zinc	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	-0.855 (0.690)	-1.438* (0.689)	-0.578 (0.578)	-0.913 (0.592)	-2.060* (0.968)	-2.962** (1.011)	-1.349 (0.760)	-1.684* (0.801)
COVOL² - 1	-2.480* (0.960)	-1.116 (0.927)	-1.352 (0.804)	-0.422 (0.797)	-3.879** (1.348)	-2.826* (1.361)	-2.953** (1.058)	-2.121 (1.078)
Inflation		6.175*** (1.351)		3.905*** (1.162)		7.028*** (1.983)		3.671* (1.572)
Investor Sentiment		-0.015 (0.015)		0.001 (0.013)		-0.005 (0.023)		0.001 (0.018)
Global Manufacturing		1.131*** (0.319)		0.817** (0.275)		0.544 (0.469)		0.696 (0.372)
China Indus. Production		0.201 (0.120)		0.187 (0.103)		0.242 (0.176)		0.154 (0.140)
Adj. R²	0.019	0.146	0.006	0.088	0.024	0.072	0.023	0.053
F-Statistic	6.674	11.091	2.826	6.697	8.279	5.581	7.791	4.263
DW Statistic	1.796	1.970	1.973	2.099	1.955	1.952	2.075	2.120
No. Obs.	295	295	295	295	295	295	295	295

Panel B: Precious Metals

	Gold		Silver		Palladium		Platinum	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.689 (0.440)	0.246 (0.465)	-0.746 (0.845)	-1.359 (0.881)	-1.968* (0.962)	-2.602* (1.018)	-1.722** (0.637)	-2.403*** (0.643)
COVOL² - 1	-0.136 (0.613)	0.136 (0.626)	-2.389* (1.176)	-1.469 (1.186)	-3.759** (1.339)	-3.331* (1.370)	-3.378*** (0.886)	-2.311** (0.866)
Inflation		2.863** (0.912)		5.237** (1.728)		4.141* (1.996)		5.952*** (1.261)
Investor Sentiment		-0.004 (0.010)		-0.017 (0.020)		-0.012 (0.023)		-0.009 (0.014)
Global Manufacturing		-0.006 (0.216)		0.721 (0.409)		0.270 (0.472)		0.729* (0.298)
China Indus. Production		0.081 (0.081)		0.281 (0.153)		0.394* (0.177)		0.210 (0.112)
Adj. R²	-0.003	0.023	0.011	0.061	0.023	0.045	0.044	0.149
F-Statistic	0.050	2.385	4.123	4.840	7.883	3.802	14.522	11.325
DW Statistic	2.261	2.259	2.241	2.272	2.001	2.008	1.958	2.058
No. Obs.	295	295	295	295	295	295	295	295

Table 5: Regression (Monthly): relationship between geopolitical risk (COVOL² - 1) and metal returns

This table shows the coefficients estimated using equations (1) and (2) as outlined above, where the dependent variable is the daily return on an industrial metal in Panel A and a precious metal in Panel B. Standard errors are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level respectively. Sample Period: June 2000 - December 2024.

Regression Results – GPR

After applying the global common volatility (COVOL) index as the key explanatory variable of the regression, it is now time to employ the geopolitical risk (GPR) index of Caldara and Iacoviello (2022) for comparative purposes as it has been used in Baur and Smales (2020).

In contrast to COVOL, the regression results demonstrate a few noteworthy impacts on metal returns, particularly for gold, suggesting possible safe-haven characteristics. It is noticeable that with ΔGPR almost all the coefficients are positive, but much less statistically significant than in the previous results of the daily and monthly regression (Table 4 & 5). These results are shown in Table 6 below.

Table 6
Regression (Daily): relationship between geopolitical risk (ΔGPR) and metal returns
Panel A: Industrial Metals

	Copper		Aluminium		Nickel		Zinc	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.025 (0.020)	0.014 (0.024)	0.009 (0.017)	0.003 (0.022)	0.007 (0.029)	0.016 (0.038)	0.015 (0.023)	0.019 (0.029)
ΔGPR	0.036 (0.052)	0.087 (0.047)	0.018 (0.045)	0.049 (0.043)	0.043 (0.078)	0.094 (0.075)	-0.035 (0.060)	0.010 (0.057)
MSCI World		0.541*** (0.018)		0.339*** (0.017)		0.541*** (0.029)		0.476*** (0.022)
USD Index		-0.581*** (0.039)		-0.465*** (0.035)		-0.471*** (0.061)		-0.501*** (0.046)
Risk free		0.459 (2.357)		0.081 (2.133)		-2.548 (3.726)		-1.643 (2.821)
Adj. R^2	-0.000	0.182	-0.000	0.110	-0.000	0.075	-0.000	0.106
F-Statistic	0.481	357.992	0.155	198.808	0.309	130.526	0.333	191.687
DW Statistic	2.122	2.159	2.042	2.088	1.944	1.957	2.024	2.067
No. Obs.	6412	6412	6412	6412	6412	6412	6412	6412

Panel B: Precious Metals

	Gold		Silver		Palladium		Platinum	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.035** (0.013)	0.023 (0.016)	0.027 (0.023)	0.016 (0.028)	0.007 (0.027)	0.022 (0.036)	0.008 (0.019)	-0.001 (0.024)
ΔGPR	0.109** (0.034)	0.107*** (0.032)	0.020 (0.061)	0.046 (0.055)	0.060 (0.073)	0.100 (0.070)	0.036 (0.049)	0.062 (0.047)
MSCI World		-0.003 (0.012)		0.307*** (0.021)		0.422*** (0.027)		0.276*** (0.018)
USD Index		-0.755*** (0.026)		-1.396*** (0.045)		-0.555*** (0.058)		-0.473*** (0.039)
Risk free		1.813 (1.604)		0.936 (2.758)		-3.133 (3.514)		0.687 (2.355)
Adj. R^2	0.001	0.122	-0.000	0.189	-0.000	0.064	-0.000	0.073
F-Statistic	10.090	224.365	0.104	374.730	0.689	110.663	0.545	127.773
DW Statistic	2.018	2.114	2.010	2.055	1.919	1.997	1.945	2.046
No. Obs.	6412	6412	6412	6412	6412	6412	6412	6412

Table 6: Regression (Daily): relationship between geopolitical risk (ΔGPR) and metal returns

This table shows the coefficients estimated using equations (1) and (2) as outlined above, where the dependent variable is the daily return on an industrial metal in Panel A and a precious metal in Panel B. Standard errors are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level respectively. Sample Period: June 2000 - December 2024.

According to the findings, industrial metals do not collectively show a statistically significant reaction to shifts in geopolitical risk. After taking financial controls into assessment, no reliable or consistent correlation with ΔGPR is seen for copper, aluminium, nickel and zinc. This implies that, especially when contrasted with more general market variables like global COVOL, geopolitical risk has minimal impact on the daily returns of industrial metals.

Then looking at the results of precious metals in Panel B, only gold stands out as ΔGPR significantly and favorably affects gold returns, which is in line with the metals reputation as a safe haven asset. Gold's ΔGPR coefficient amounts to 0.107, statistically significant at the 1% (***) level. This means that, on average daily gold returns rise by 0.107 percentage points for every unit increase in ΔGPR. The coefficients for the other three precious metals are positive (different to the results using COVOL) but not statistically significant. The regression using monthly data for ΔGPR can be found in the Appendix D.

Overall, it can be said that the results – specifically for Panel B: Precious Metals – are aligned with the findings of Baur and Smales (2020). This might be due to less impactful spikes of the GPR index within the different sample period, as for example the first gulf war or the US attacks on Libya in 1986 caused severe jumps of the geopolitical index. In the sample period applied in the study here they were not included, whereas events such as the pandemic in early 2020 had almost no impact on the GPR index.

When evaluating the outcomes of the regressions with the COVOL and GPR indices, it is crucial to note that the unique characteristics of the risks that each index measures account for a significant portion of their effects on metal returns. The COVOL index measures widespread, ongoing market-wide uncertainty (such as financial crises or COVID-19), which has a larger impact on investor sentiment and industrial activity than the GPR index, which represents discrete, event-driven geopolitical conflicts that may increase demand for safe haven assets, particularly precious metals. The GPR index seems to have less statistically consistent and long-lasting effects on metal returns than COVOL. whereas the impact of COVOL on industrial metals is more evident and continuously negative.

Comparison: Global COVOL vs GPR index

Finally, a regression is performed solely focusing on the two geopolitical risk indexes as the key explanatory variables without controlling for any other variables to better quantify how much each of the two captures of the returns of the industrial and precious metals.

Table 7
Regression (Daily): relationship between $COVOL^2 - 1$, ΔGPR and metal returns

Panel A: Industrial Metals

Regression	Copper	Aluminium	Nickel	Zinc
Constant	-0.053 (0.028)	-0.044 (0.024)	-0.083* (0.041)	-0.057 (0.032)
$COVOL^2$ - 1	-0.144*** (0.036)	-0.098** (0.031)	-0.165** (0.054)	-0.132** (0.041)
ΔGPR	0.036 (0.052)	0.018 (0.045)	0.043 (0.078)	-0.035 (0.060)
Adj. R^2	0.002	0.001	0.001	0.001
F-Statistic	8.127	4.957	4.879	5.239
DW Statistic	2.127	2.046	1.947	2.027
No. Obs.	6412	6412	6412	6412

Panel B: Precious Metals

Regression	Gold	Silver	Palladium	Platinum
Constant	0.014 (0.018)	-0.017 (0.033)	-0.019 (0.039)	-0.039 (0.026)
$COVOL^2$ - 1	-0.039 (0.024)	-0.081 (0.043)	-0.047 (0.050)	-0.086* (0.034)
ΔGPR	0.109** (0.034)	0.020 (0.061)	0.060 (0.073)	0.036 (0.049)
Adj. R^2	0.002	0.000	-0.000	0.001
F-Statistic	6.394	1.883	0.773	3.487
DW Statistic	2.019	2.011	1.919	1.947
No. Obs.	6412	6412	6412	6412

Table 7: Relationship between $COVOL^2$ - 1, ΔGPR and metal returns

This table shows the coefficients applying both geopolitical risk indexes as an explanatory variable. Industrial metals are shown in Panel A and a precious metal in Panel B. Standard errors are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level respectively. Sample Period: June 2000 - December 2024.

According to the findings in Panel A, coefficients for global common volatility (COVOL) continue to be negatively and statistically significant across all industrial metals. As previous regression results revealed, these findings confirm how sensitive industrial metals are to general market instabilities and times of increased risk aversion among investors. On the other hand, the positive coefficients for ΔGPR become statistically insignificant, indicating that geopolitical risk as captured by the GPR index has low explanatory power for daily changes in industrial metal prices when global common volatility is taken into consideration.

Of all the precious metals analyzed, gold shows a statistically significant relationship with ΔGPR, all other coefficients are insignificant. This outcome demonstrates that gold can profit from increased tensions between countries regardless of the state of the financial markets, serving as a geopolitical safe haven. Silver, palladium, and platinum seem less consistently responsive to changes in geopolitical factors. Furthermore, none of the precious metals are significantly impacted by global common volatility but platinum, contrary to ΔGPR which seems to be irrelevant.

When both risk measures are taken into account, COVOL remains to have a negative and substantial effect on all industrial metals, while ΔGPR continues to have its only major impact on gold returns. This implies that each of the risk classifications interact through different channels: COVOL reflects general financial market turmoil, causing damage to industrial metals, while changes in the GPR index represent geopolitical tensions and military conflicts, which result in benefits for gold.

Investing in Industrial Metals

As it has been shown in the empirical analysis above, industrial metals do not serve as appropriate hedges against geopolitical risk, given the negative coefficients in the daily regression (Table 4). These findings show that the returns of copper, aluminium, nickel and zinc tend to respond negatively to heightened geopolitical tensions. Therefore, investing in industrial metals is risky in times of geopolitical unpredictability as the demand for industrial metals usually declines when production slows, supply chains may be disrupted, and market sentiment commonly turns risk averse. Still, industrial metals continue to be attractive investments over the long run since geopolitical crises usually show up as rapid, temporary peaks rather than lasting disruptions as clearly illustrated in Figure 3 and 4.

Overtime, there are two main aspects that are expected to contribute positively to the price development of industrial metals. First, as mentioned earlier, the production of essential parts for the clean energy transition, including batteries for electric vehicles, depend heavily on industrial metals and second commodities overall have long served as strong inflation protection in investors' portfolios. This has been especially true during periods when price hikes in many industrialized nations have reached decades-high levels.

Another advantage of this type of asset is the likelihood of a large rise in supply to be relatively assessable as it takes years for metal mines to advance from the initial investment to the production phase. Thereby, the adherence to ESG standards creates obstacles for mining companies, resulting in limiting new supply. However, headwind is caused by the declining grade of ore, facing both new and existing mines. When metals are produced from lower-grade ores, extraction becomes more technically challenging, and processing requirements include stronger machinery and more chemicals. This in turn, causes an increase in demonstrations against new mines, as operations gets potentially "dirtier" (Hirt, 2022).

When considering exposure to industrial metals, investors need to be aware of the possible risks connected to investment strategies. Major futures exchanges in New York, London and Shanghai are the main hubs where industrial metals are traded – for industrial investors. Further, exchange-traded products (ETPs), which can be traded like listed shares, provide access to contracts listed on the London Metal Exchange and Comex. This kind of ETPs might track the performance of a specific metal or a basket of metals through an index such as the Bloomberg Industrial Metals Index (Hume, 2025).

A passive approach by taking advantage of a widely recognized index fund could facilitate entering the market. The most widely used benchmark for passive commodity strategies, the S&P Goldman Sachs Commodity Index (GSCI) Index, might be an attractive option, though has with only 10% a low allocation in industrial metals and a substantial energy bias. In comparison, the Bloomberg Commodity ex Agriculture/Livestock Index has a holding in industrial metals that is roughly twice as high, making it more positioned to gain from the energy transition (Hirt, 2022).

Investing in the stocks of listed mining companies is another way to gain exposure. The four largest and most diversified mining corporations in the world, namely Anglo American, BHP, Glencore, and Rio Tinto, are all listed in London and provide different levels of exposure to industrial metals. Additionally, actively managed funds are another option to invest in the sector, which have usually heavy weights in the before mentioned equities (Hume, 2025).

Bessler and Wolff (2020) revealed in their study that for any asset allocation strategy, the S&P GSCI, its energy lighter equivalent, and industrial metals continuously improve the risk-return profile of a stock-bond portfolio, according to the Sharpe ratio and Omega measure. Furthermore, they discovered that across all strategies, industrial metals provide the most Sharpe ratio advancement, with aggregate commodity indexes coming in second. Nevertheless, industrial metals do not improve stock-bond portfolio performance during recessions, which is unsurprising considering that the demand for industrial metals is pro-cyclical, typically reflecting a tendency to rise during economic expansion and fall during recessions. When observing more closely sovereign debt markets, Agyei-Ampomah et. al. (2013) argue that industrial metals' elevated status in safeguarding investors from losses in US and European bonds may be caused by the growing demand for these metals from emerging countries like the BRICS.

To sum up, industrial metals may present a chance for investors who do not have commodities in their investment portfolio to reduce the exposure to inflation or benefit from the economic tendency towards higher usage of metals. Investors already committed to the asset class but possibly too much energy loaded, might adopt a strategy to increase its diversification and possible returns when making investments in industrial metals (Hirt, 2022).

Conclusion

This study tests whether industrial metals, namely copper, aluminium, nickel, and zinc, serve as appropriate safe-haven investments or hedges in times of increased geopolitical risk. Over the period between June 2000 to December 2024, daily and monthly regression analyses have been performed to examine market behaviors in response to geopolitical risk, employing the global common volatility (COVOL) index as a broad measure of geopolitical risk.

The empirical results represent a clear takeaway, being industrial metal returns generally falling in times of elevated geopolitical risk. The findings suggest that the analyzed metals do not serve as effective hedges or safe havens due to their negative relationship with COVOL. In contrast to gold and US Treasuries, which are traditionally thought of as investments that preserve or increase in value during times of crisis, industrial metals seem to be more exposed to risk-averse sentiment in international markets.

Surprisingly, precious metals did not consistently express robust safe-haven behavior either, a finding contrary to the ones of Baur and Smales (2020) and many comparable studies, which commonly apply the news-based GPR index of Caldara and Iacoviello (2022) to gauge geopolitical risk. In this research, only platinum showed a statistically significant reaction to higher COVOL levels, whereas palladium, silver, and gold remained essentially unaffected.

Even though industrial metals might not be able to protect against geopolitical fluctuations, they are still valuable assets from an investing point of view. It is anticipated that the intensifying energy transition, worldwide electrification, and decarbonization initiatives will result in a substantial surge in the long-term demand for these metals. Furthermore, industrial metals continually provide significant portfolio diversification advantages and protection from inflation. Industrial metals, pro-cyclical and macroeconomic sensitive returns can improve a diversified portfolio's risk-return profile, particularly in long-term investment horizons.

The findings of this thesis support the belief that, especially during times of industrial expansion or growing inflation, investors should consider industrial metals as strategic investments in line with fundamental economic trends rather than as safe havens.

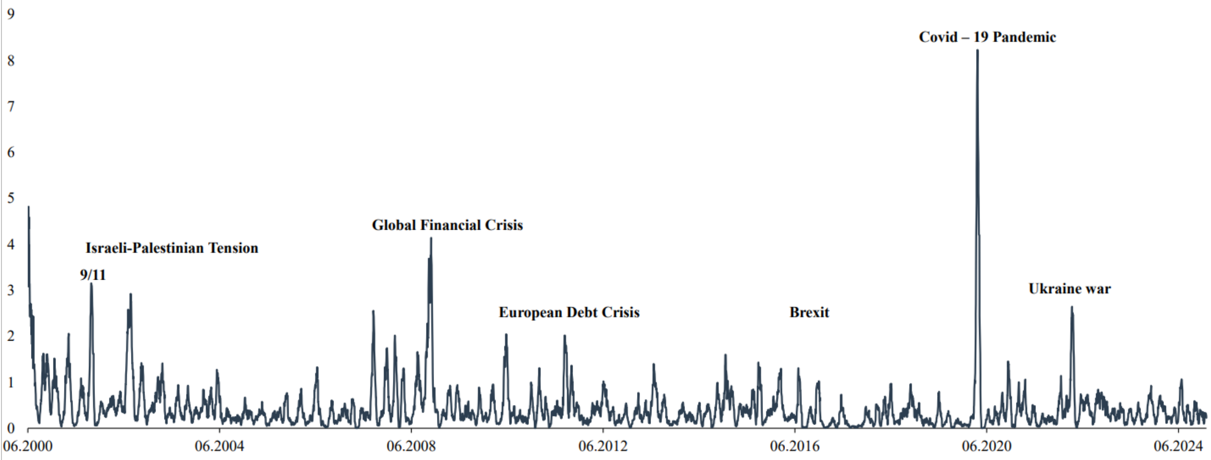
This study adds to the existing literature that attempts to find explanations of how financial markets and geopolitical events interact. By concentrating on industrial metals, a less frequently researched asset class in this regard, it addresses a gap and offers valuable information for both academic research and real-world portfolio management.

Additional study on the topic could apply regional GPR indexes to reveal forms in which geographically concentrated conflicts impact price dynamics and hedging capabilities across metals, particularly in large economies. Also, future studies might analyze how industrial metals react to global volatility and determine whether their responsiveness is unique or a part of a larger commodity market trend by applying the COVOL index across several commodity sectors, such as energy or agriculture.

In conclusion, industrial metals long-term value derives from their ability for economic diversification and importance, even though they might not provide instant protection against geopolitical upheavals. To effectively manage an increasingly challenging global risk environment, investors and policymakers must understand this distinction.

Appendix

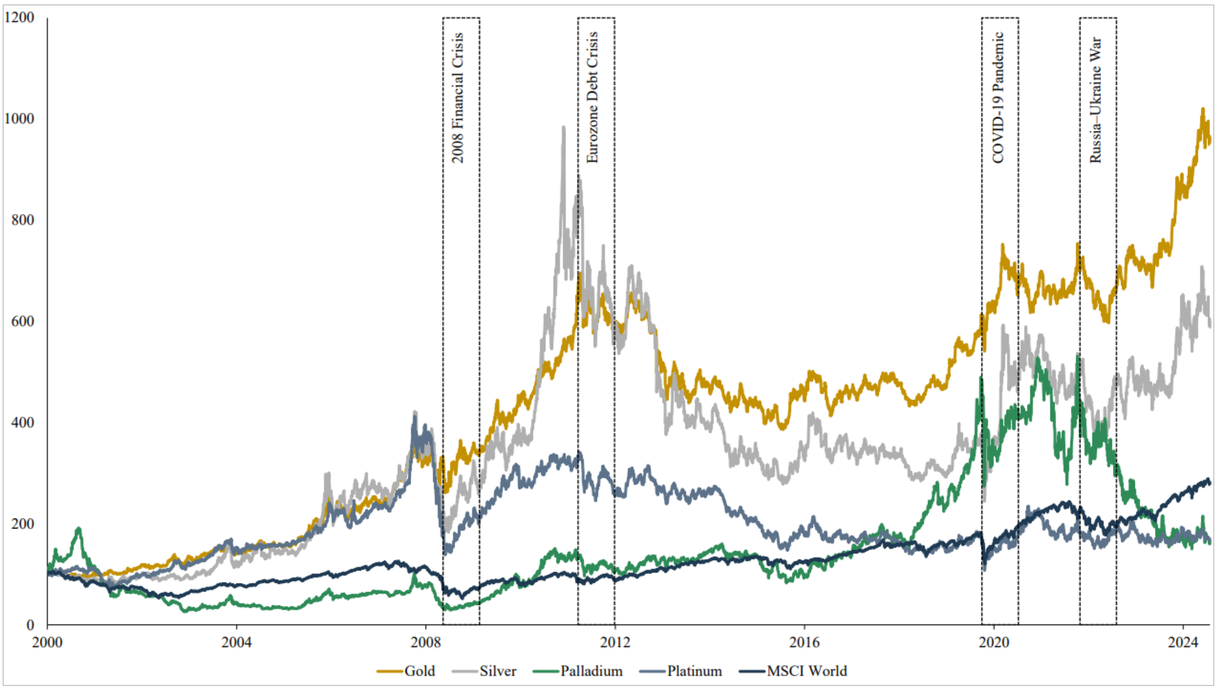
Appendix A: Global Common Volatility (COVOL) Index – Daily



Appendix A: Global Common Volatility (COVOL) Index Daily Data

This graph plots the daily global COVOL Index (here COVOL²) over the period 2000 – 2024. Source: "What are the events that shake our world? Measuring and hedging global COVOL" by Robert F. Engle and Susana Campos-Martins (2022).

Appendix B: Precious Metals Price Development



Appendix B: Precious Metals Price Development

This graph depicts the history of the analyzed precious metals and the MSCI World over the period June 2000 – December 2024. Prices are rebased to 100 as of June 2000. Daily Data.

Appendix C: Correlation Matrix: ΔGPR - Control Variables

Appendix C

Panel A: Correlation Matrix Control Variables - Daily

	ΔGPR	MSCI World	USD Index	Risk free
ΔGPR	1.000	**-0.036**	-0.002	0.000
MSCI World		1.000	**-0.263**	-0.008
USD Index			1.000	-0.007
Risk free				1.000

Panel B: Correlation Matrix Control Variables - Monthly

	ΔGPR	Inflation	Investor Sentiment	Global Manufacturing	China Indus. Production
ΔGPR	1.000	0.072	0.059	-0.006	0.077
Inflation		1.000	0.045	**0.294**	0.008
Investor Sentiment			1.000	**0.145**	-0.082
Global Manufacturing				1.000	*-0.109*
China Indus. Production					1.000

Bold font indicates significant at the 5% level and italic font indicates significant at 10% level.

Appendix C: Correlation Matrix for ΔGPR and Control Variables

Correlation between ΔGPR and the financial control variables for the daily regression as well as the macroeconomic control variables used for the monthly regression.

Appendix D: Regression (Daily): relationship between geopolitical risk (ΔCOVOL²) and metal returns

Appendix D
Regression (Daily): relationship between geopolitical risk (ΔCOVOL²) and metal returns
Panel A: Industrial Metals

	Copper		Aluminium		Nickel		Zinc	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.025 (0.020)	0.014 (0.024)	0.009 (0.017)	0.003 (0.022)	0.007 (0.029)	0.016 (0.038)	0.015 (0.023)	0.019 (0.029)
ΔCOVOL²	-0.823*** (0.208)	-0.009 (0.190)	-0.611*** (0.181)	-0.081 (0.172)	-1.058*** (0.310)	-0.268 (0.300)	-0.969*** (0.238)	-0.256 (0.227)
MSCI World		0.539*** (0.018)		0.338*** (0.017)		0.537*** (0.029)		0.473*** (0.022)
USD Index		-0.582*** (0.039)		-0.466*** (0.035)		-0.472*** (0.061)		-0.500*** (0.046)
Risk free		0.460 (2.358)		0.088 (2.133)		-2.526 (3.727)		-1.621 (2.821)
Adj. R^2	0.002	0.182	0.002	0.110	0.002	0.075	0.002	0.106
F-Statistic	15.620	356.958	11.447	198.496	11.672	130.310	16.522	192.033
DW Statistic	2.127	2.159	2.046	2.088	1.945	1.956	2.029	2.067
No. Obs.	6412	6412	6412	6412	6412	6412	6412	6412

Panel B: Precious Metals

	Gold		Silver		Palladium		Platinum	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.035** (0.013)	0.023 (0.016)	0.027 (0.023)	0.016 (0.028)	0.006 (0.027)	0.021 (0.036)	0.007 (0.018)	-0.002 (0.024)
ΔCOVOL²	-0.178 (0.137)	-0.033 (0.129)	-1.281*** (0.245)	-0.612** (0.222)	-1.353*** (0.290)	-0.705* (0.283)	-0.993*** (0.195)	-0.550** (0.190)
MSCI World		-0.005 (0.013)		0.300*** (0.022)		0.413*** (0.027)		0.269*** (0.018)
USD Index		-0.756*** (0.026)		-1.395*** (0.045)		-0.555*** (0.057)		-0.472*** (0.039)
Risk free		1.816 (1.605)		0.988 (2.757)		-3.073 (3.513)		0.734 (2.354)
Adj. R^2	0.000	0.121	0.004	0.190	0.003	0.065	0.004	0.074
F-Statistic	1.699	221.250	27.463	376.853	21.743	111.786	25.858	129.586
DW Statistic	2.021	2.115	2.015	2.056	1.930	2.000	1.960	2.052
No. Obs.	6412	6412	6412	6412	6412	6412	6412	6412

Appendix D: Regression (Daily): relationship between geopolitical risk (ΔCOVOL²) and metal returns

This table shows the coefficients estimated using equations (1) and (2) as outlined in the empirical analysis section, where the dependent variable is the daily return on an industrial metal in Panel A and a precious metal in Panel B. Standard errors are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level respectively. Sample Period: June 2000 - December 2024.

Appendix E: Regression (Monthly): relationship between geopolitical risk (ΔGPR) and metal returns

Appendix E
Regression (Monthly): relationship between geopolitical risk (ΔGPR) and metal returns

Panel A: Industrial Metals

	Copper		Aluminium		Nickel		Zinc	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.551 (0.426)	-0.832 (0.482)	0.188 (0.354)	-0.679 (0.414)	0.145 (0.600)	-1.467* (0.711)	0.330 (0.471)	-0.560 (0.563)
Δ GPR	1.894 (1.881)	1.218 (1.754)	1.542 (1.565)	0.981 (1.506)	0.112 (2.653)	-0.828 (2.590)	0.109 (2.080)	-0.423 (2.051)
Inflation		6.277*** (1.349)		3.913*** (1.158)		7.513*** (1.992)		4.024* (1.577)
Investor Sentiment		-0.016 (0.016)		0.001 (0.013)		-0.004 (0.023)		0.001 (0.018)
Global Manufacturing		1.208*** (0.314)		0.849** (0.270)		0.721 (0.464)		0.829* (0.368)
China Indus. Production		0.187 (0.120)		0.179 (0.103)		0.227 (0.178)		0.143 (0.141)
Adj. R^2	0.000	0.144	-0.000	0.089	-0.003	0.059	-0.003	0.040
F-Statistic	1.015	10.861	0.970	6.729	0.002	4.672	0.003	3.452
DW Statistic	1.687	1.932	1.903	2.081	1.869	1.910	1.992	2.085
No. Obs.	295	295	295	295	295	295	295	295

Panel B: Precious Metals

	Gold		Silver		Palladium		Platinum	
Regression	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.762** (0.267)	0.191 (0.323)	0.605 (0.518)	-0.553 (0.616)	0.163 (0.594)	-0.810 (0.717)	0.192 (0.397)	-1.150* (0.453)
Δ GPR	2.194 (1.182)	1.880 (1.178)	3.178 (2.291)	2.520 (2.242)	2.766 (2.627)	2.015 (2.612)	3.049 (1.753)	2.338 (1.650)
Inflation		2.734** (0.906)		5.318** (1.724)		4.540* (2.009)		6.175*** (1.269)
Investor Sentiment		-0.005 (0.010)		-0.019 (0.020)		-0.013 (0.023)		-0.010 (0.015)
Global Manufacturing		-0.005 (0.211)		0.828* (0.402)		0.493 (0.468)		0.889** (0.296)
China Indus. Production		0.072 (0.081)		0.257 (0.154)		0.361* (0.179)		0.182 (0.113)
Adj. R^2	0.008	0.031	0.003	0.060	0.000	0.028	0.007	0.134
F-Statistic	3.445	2.906	1.925	4.782	1.109	2.691	3.026	10.129
DW Statistic	2.247	2.252	2.180	2.247	1.941	1.984	1.845	2.010
No. Obs.	295	295	295	295	295	295	295	295

Appendix E: Regression (Monthly): relationship between geopolitical risk (ΔGPR) and metal returns

This table shows the coefficients estimated using equations (1) and (2) as outlined in the empirical analysis section, where the dependent variable is the daily return on an industrial metal in Panel A and a precious metal in Panel B. Standard errors are reported in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level respectively. Sample Period: June 2000 - December 2024.

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