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Metal price behaviour during recent crises: COVID-19 and the Russia–Ukraine conflict

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Orientation: Commodities are a prominent feature of the global economy. A substantial component of the income and welfare of both commodity-producing and commodity-consuming countries is highly dependent on the prices of commodities, such as metals. Metal prices are driven by economic growth and provide important insight into the state of the global economy: this behaviour is inextricably linked with the transitory shocks.

Research purpose: Understanding recent metal price behaviour provides information about the economic implications of the coronavirus disease 2019 (COVID-19) pandemic as well as the Russia–Ukraine conflict. This research engages with the notion of the ongoing upward swing of the post-2000 super-cycle in the metals market.

Motivation for the study: An analysis of metal price behaviour during COVID-19 and the Russia–Ukraine conflict describes the consequences of market shocks on commodity prices and examines the role played by super-cycles within metal markets. This work measures the optimal performances of portfolios comprising precious and nonprecious metals.

Research approach/design and method: Portfolio optimisation using Lagrangian calculus under various constraints. The article argues that transitory shocks from pandemics and conflicts have a positive relationship with risk–return profiles of relevant portfolios.

Main findings: A positive correlation was found between transitory shocks and prices of both precious and nonprecious metals. There is also evidence regarding the continuation of the post-2000 super-cycle in the metals market.

Practical/managerial implications: Better knowledge of these relationships allows commodity traders to confidently assert that metal commodities will deliver healthy returns at moderate risk levels during periods that are characterised by different transitory shocks. Metals exist and exhibit safe haven properties during periods governed by economic uncertainty.

Contribution/value add: Metals have exhibited strong economic performances in an economic landscape where little has flourished. This consequently affirms their importance and outlines their investment viability during volatile and uncertain periods.

Keywords: Super-cycle; metal prices; COVID-19; Ukraine; efficient frontier.

Introduction

Commodities and the subsequent trade thereof are a prominent feature of the global economy. A substantial component of the relative income and welfare of both commodity-producing and commodity-consuming countries is largely dependent on the prices of commodities. Moreover, commodity price movements stimulate capricious macro-economic activity within emerging markets and developing economies (EMDEs). Energy and metal commodities serve as substantial contributors to fiscal and export revenue amongst almost two-thirds of EMDEs (World Bank 2021). The understanding of commodity price booms and busts is consequently an important component of global finance. This work provides an analysis of metal prices during the coronavirus disease 2019 (COVID-19) pandemic and the Russia–Ukraine conflict, explores the consequences of each market shock on commodity prices and investigates the role played by super-cycles within metal market and the subsequent implications thereof.

Super-cycles in the metal market detail 10–35-year expansionary phases that stimulate prolonged growth in prices. These cycles can extend beyond 70 years in their entirety, and this makes them particularly difficult to track; however, the understanding of these periods is a fundamental feature of the commodity sector (Erten & Ocampo 2012). This article explores the state of the post-2000 super-cycle and determines whether recent price behaviour has been influenced by an ongoing upward swing within said super-cycle.

The considerable increase in uncertainty during the COVID-19 pandemic had a significant effect on the real economy and the financial milieu. There has been a negative stock market response and widespread evidence of COVID-19-induced uncertainty hampering the real gross domestic product (GDP) growth of 210 countries (Bakas & Triantafyllou 2020). The pandemic plunged the global economy into recession, and the commodity markets across the board were adversely affected by the disease. The price of the metals investigated all saw notable decreases upon the arrival of the pandemic in March 2020. However, unlike the oil markets, metals recovered rapidly, reaching prepandemic peaks and beyond within a relatively short space of time (months, rather than years).

The objective of this work is to establish relationships between market shocks (such as the pandemic and the Russia–Ukraine conflict) and movements in metal prices. Both shocks precipitated considerable disruption of the global supply chain (Guénette, Kenworthy & Wheeler 2022), resulting in a period characterised by elevated volatility (the pandemic halted global growth through reduced economic activity, and the war affected various commodity prices because of e.g. severe economic sanctions). In addition, this article applies the role of volatility within business cycles as a means of differentiating the natures of transitory and permanent shocks. This serves to provide further insight regarding the implications of these shocks within metal markets. Understanding the nuances of these shocks is paramount to the understanding of metal price behaviour in the context of business cycle horizons, as transitory and permanent shocks drive variation in metal markets.

Commodities prices are driven by aggregate supply and demand shocks, whereby the price elasticity of both supply and demand tend to increase in periods characterised by economic disruption, which in turn results in a perpetual decrease in supply and demand (Bakas & Triantafyllou 2020). Commodity prices are also susceptible to shocks, either permanent or transitory. Examples of transitory shocks include recessions, *ad hoc* policy measures, adverse weather conditions, accidents and conflicts. The 2008 global financial crisis (GFC) is one of the most severe financial shocks in history, owing to its devastating impact on supply and demand across a wide range of assets – including commodities. Permanent shocks tend to be associated with policy and technology. An example of this would be the development of shale technology within the crude oil and natural gas industries, which resulted in the United States (US) being the world’s largest oil producer in 2019 (Baffes & Kabundi 2021). To this end, COVID-19 and the Russia–Ukraine conflict are deemed to be transitory shocks that have disrupted the global economy.

Literature review

This literature review details a three-step analysis of previous research regarding metal price cycles. The review begins by exploring empirical research pertaining to metal price cycles and the presence of market super-cycles. This is supplemented by the examination of research relating to relative shocks that are interwoven in the fabric of the commodity sector. Focus is directed towards exogenous transitory shocks, including the COVID-19 pandemic, war and conflict.

Commodity price cycles

Kondratieff (1926) and Schumpeter (1939) are responsible for the development of the major analytical frameworks that underpin commodity cycles. Kondratieff (1926) documented the presence of long swings ranging from 40 to 60 years using interest rates, commodity prices, industrial production and foreign trade. Kondratieff (1926) repudiated any exogenous factors such as war, gold production or revolution in favour of endogenous factors, wherein technological advancement and capital accumulation were held to be the driving forces behind these long swings. Schumpeter (1939) took significant inspiration from Kondratieff’s ideas, specifically in terms of endogeneity as the driving force; however, he postulated entrepreneurial innovation to be the key factor regarding the growth and contraction of these extensive cycles (Schumpeter 1939). Multiple overlapping cycles of various durations (Kondratieff cycles of roughly 50 years, Juglar cycles of 9 years and Kitchen cycles of 3 years) were identified. Schumpeter (1939) argued that Kondratieff cycles rested on the tenets of his theory of creative destruction, whereby dynamic investment opportunities coupled with technological innovation stimulate economic growth in emerging sectors in tandem with the erosion of obsolete sectors characterised by outdated methods of production.

Jacks (2019) argues that real commodity price series are a product of long-run trends, medium-run cycles and short-run boom–bust episodes. Real commodity prices spanning over an extended timeframe are largely influenced by how long of a period is considered, as well as how a given commodity is weighted when constructing relative price indices. Consequently, long-run trends in real commodity prices are inordinately swayed by happenings in either the distant or recent past (Bazzi & Blattman 2014). Moreover, there is a consistent pattern of commodity price cycles that are characterised by medium-run swings in real commodity prices. These are demand-driven episodes that tend to occur on the back of periods of mass industrialisation and urbanisation (namely in the energy, minerals and metals markets) as a means of creating above-trend real commodity prices (Jacks 2019).

Metal prices tend to have asymmetric impacts, with price increases relating to small, temporary economic expansion and price decreases associated with growth slowdowns during recessions (Rossen 2015). However, China’s economic and industrial expansion has created an aggregate global demand shock with a magnitude that challenges the aggregate demand shocks synonymous with global recessions (World Bank 2021). The sheer magnitude of China's material-intensive economic growth is such that Heap (2005) asserted that it would serve as a catalyst for a new super-cycle. Expansionary-driven price increases in metals is emphasised by China's growth in the beginning of the century. However, the proposition that decreasing prices correlate with recessions is insufficient for this work because metal prices recovered to prepandemic peaks during the COVID-19-induced recession (Zhu, Xu & Cheng 2020).

Super-cycles

Cycles are 'super' in terms of period: upswings can last between 10 and 35 years, meaning complete cycles will span between 20 and 70 years. Cuddington and Jerrett (2008) affirmed that they are broad-based, affecting a plethora of commodities including metals and nonrenewable resources. Heap (2005) defines super-cycles as 'prolonged (decades) long-trend rises in real commodity prices, driven by urbanisation and industrialisation of a major economy'. Jerrett and Cuddington (2008) argue that China's economic expansion in tandem with its mass urbanisation could have undoubtedly stimulated a super-cycle. According to Erten and Ocampo (2012), the periodisation of super-cycles for real metal prices are captured by the following: 1885–1921, 1921–1945, 1945–1999 and 1999–ongoing. They further argue that the resilience of China's growth performance at the beginning of the century is tantamount to the considerable length and strength of the upswing in commodity prices. Heap (2005) argues that the Chinese-led post-2000 episode was the vehicle for the most recent super-cycle, and his claim is further supported by Cuddington and Jerrett (2008). The post-2000 episode refers to the beginning of the most recent super-cycle, and the upward swing serves to describe the expansionary phase of the super-cycle. The expansionary phase is characterised by high prices – these will undergo periodic dips and deviations; however, prices are found to exhibit upward trends across 10–35-year periods (Erten & Ocampo 2012). The role of unique nontrend components is receiving growing attention, as periods characterised by high levels of volatility stimulate business cycles and strikingly large, short-term fluctuations tend to accompany long-term trends and super-cycles in real commodity prices (Erten & Ocampo 2012).

The pandemic and the Russia–Ukraine war can be likened to previous nontrend shocks that disturb business cycles and medium-term factors. The interwar period in the 20th century serves as a period with substantial volatility (in terms of business cycle and medium-term factors) that ultimately coincided with the dawn of a new super-cycle in the metal market.

Permanent and transitory shocks

The commodity sector is susceptible to shocks that have a tangible impact on aggregate supply and demand. The nature and origin of these shocks determines whether they have a transitory or permanent effect amongst different commodities. Price cycles comprise these transitory or permanent components, wherein permanent shocks tend to affect the commodity sector as a whole, whereas transitory shocks will affect individual commodities (World Bank 2021). Transitory shocks serve as catalysts for medium- and short-term cycles. Baffes and Kabundi (2021) state that transitory shocks can be a product of *ad hoc* policy measures like the bans regarding grain exports during the food price spikes between 2007 and 2011. Adverse weather conditions such as droughts or flooding tend to have a prominent impact on the agricultural sector, whilst accidents, conflicts and terrorist attacks all serve as additional examples of different sources of transitory shocks (Baffes & Kabundi 2021). Permanent shocks tend to originate from policy changes and technology advancement, which in turn implicate long-lasting impacts on commodity markets and prices. An example would be when the US development of shale technology in crude oil and natural gas industries resulted in the US becoming a net energy exporter in 2019 as well as the largest producer of oil for the first time since 1952 (World Bank 2021).

Advancements in biotechnology throughout the Nineties produced a notable 20% increase in crop productivity. Policy developments supporting the production of biofuels prompted a 4% shift of global land from food to biofuel production. Permanent shocks are responsible for an average of 46% in price variability across all commodities, whereas transitory shock-driven medium and short-term cycles account for 33% and 17% of verifiability, respectively (Baffes & Kabundi 2021). Furthermore, business cycles account for 24% of variability in real metal prices. The notable contribution of business cycle shocks to metal market fluctuations are underpinned by the strong correlation between metal consumption and industrial activity. Growing industrial activity is often associated with increased activity within the mining industry, which in turn is a by-product of populous investment that subsequently promotes changes in metal prices (World Bank 2020). An investment-driven cycle refers to the process of bringing new discoveries to light within the energy and metal commodity sectors. This denotes a costly production process that incurs sizeable and sometimes irreversible investment. For example, the boom in metal prices at the turn of the 21st century is partially attributed to extensive development and exploration costs in relation to new mineral deposits (Marañon & Kumral 2019). The time needed to develop different resources is also dependent on multiple factors, such as the magnitude and grade of the deposit, country-specific factors and financing conditions. Resource development of gold (as a precious metal) takes about 10 years, whereas most base metals will take more than 15 years (Baffes & Kabundi 2021).

Transitory shocks have contrasting effects on different commodity markets. Oil and metal prices are asymmetric; price changes are inclined to move in the same direction as the relevant transitory economic expansion or contraction (World Bank 2021). There have been numerous periods that have resulted in considerable price jumps and collapses in metal prices. These periods are clustered around significant economic events, including the four recessions (1974–1975, 1981–1982, 1990–1991 and 2008–2009) prior to 2020. Prices also reacted to the global slowdowns in 1998, 2001 and 2012. Metal prices decline in close correlation with recessions and proceed to rise in tandem with the subsequent recovery of the global economy (World Bank 2021).

Evidence from the COVID-19 pandemic bolsters the sentiment of unparalleled reactions to transitory shocks. The virus plunged the global economy into a recession wherein almost all commodity prices were initially adversely affected. Figure 1a and b illustrate the decline amongst metal prices after the onset of the pandemic.

The decline in prices is unsurprising in the oil markets as hard lockdowns and limited travel eliminated demand. On the other hand, metal prices fell as much as 16% during the early stages of the COVID-19. Later, however, many metals regained their prepandemic peak prices, with several metals reaching their highest prices in decades (World Bank 2021).

The response of the metal market to COVID-19 bears almost no resemblance to that of the GFC. Metal prices embarked on slow recovery on the back of 2008, whereas certain metals reached record highs during the same calendar year as the inception of the COVID-19. Empirical research offers two possible explanations: price recovery exists in correlation with the ongoing upward swing of a new super-cycle in the metals market (Erten & Ocampo 2012) and price increases could be attributed to the energy transition – the cognisant move to use more sustainable energy worldwide – developed upon a metal-intensive process. The energy transition is indicative of an investment boom that may exist in correlation with a business cycle or mark the beginning of an investment-driven medium-run cycle (Baffes & Kabundi 2021).

The pandemic and the Global Fear Index

Salisu, Akanni and Raheem (2020) developed the COVID-19 Global Fear Index (GFI) that sought to quantify daily concerns and emotions on the spread and severity of COVID-19 since the beginning of the pandemic. The idea was that excessive fears and paranoia could have dramatic implications on investment sentiments and decisions, consequently having an adverse effect on commodity prices. The estimated coefficient indicates a positive impact of the GFI on commodity price returns. Salisu et al. (2020) determined that investors can exploit wealth protection features of commodities by spreading portfolios from shares and bonds during times of crisis. These results correlate to those of empirical economics in terms of hedging commodities, namely precious metals such as gold, silver and palladium.

According to Borgards, Czudaj and Hoang (2021), precious and industrial metals prove to be a better hedge and somewhat of a haven in comparison with other commodities. The positive response of precious metal volatility to the COVID-19 is in line with the haven properties of precious metals during recessionary periods (Bakas & Triantafyllou 2020). This in tandem with Salisu et al.'s (2020) delivery of a positive correlation between the GFI and commodity price returns suggests that the recovery and subsequent jump of metal prices during the pandemic are in correlation with empirical economic research. Furthermore, Umar, Gubareva and Teplova's (2021) investigation of portfolio diversification during COVID-19-induced panic affirmed precious metals to possess attractive hedging attributes, whilst nonprecious metals are deemed to exemplify superior diversification potential during the recovery from recession and global crises.

Data and methodology

Data

This article focuses on efficient frontiers of commodity portfolios that comprise a combination of precious and base (nonprecious) metals, specifically focusing on the minimum-variance and tangent (maximum Sharpe ratio) portfolios. A 5-year period is considered which exists as a tracking medium for the upward swing of the post-2000 super-cycle in the metal market (Erten & Ocampo 2012).

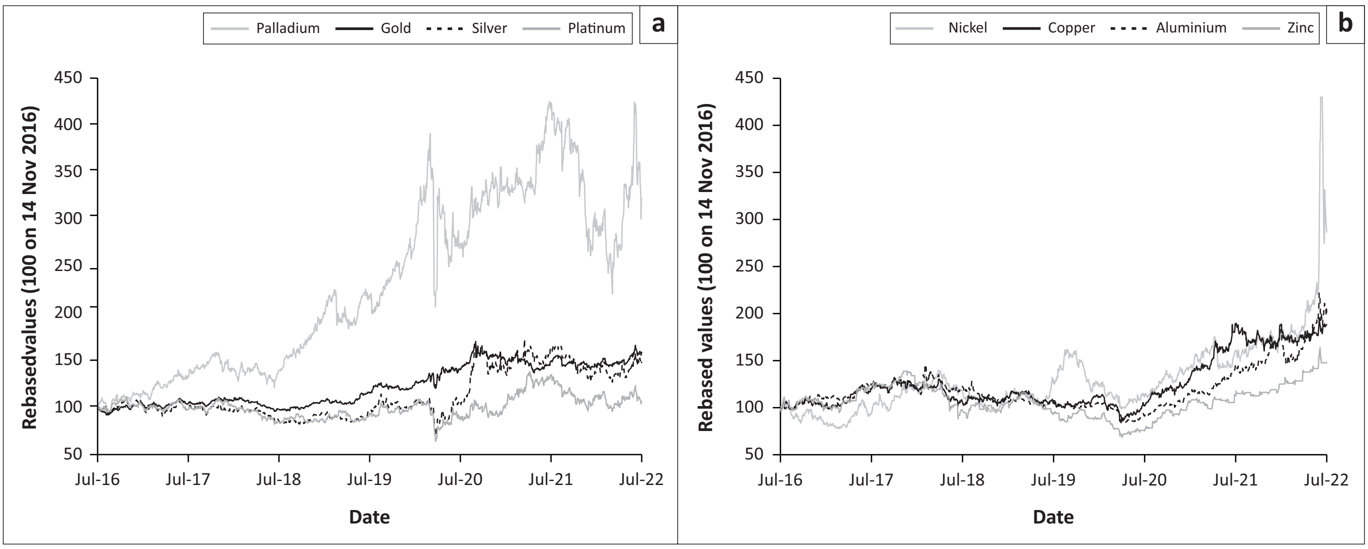

FIGURE 1: Daily prices of (a) precious (silver, gold, platinum, palladium) and (b) nonprecious (*copper, nickel, aluminium, zinc) metals between July 2016 and July 2022*.

Metals have different practical functions that serve to cultivate a variety of responses to changing market conditions. The analysis was conducted on four precious metals (silver, gold, platinum, palladium) and four base metals (copper, nickel, aluminium, zinc). Base metals tend to corrode, tarnish or oxidise far easier than precious metals, and they are cheaper and more readily extractible than their precious counterparts. Copper is used in electrical wiring because of its high ductility and conductivity, whereas nickel is used as an alloying element in steels, cast irons and nonferrous alloys (Bell 2019). Precious metals are rare and generally chemically inert. They are sometimes used in industrial capacities, but their principal function is the storing of economic value: in times of prevailing crises, gold, amongst other precious metals, is considered a reliable hedge in terms of portfolio diversification (Umar et al. 2021). The contrasting economic and practical functions of these metal groups lend themselves to the comprehensive analysis of metal price behaviour as well as relevant comparisons between them.

This article considers three portfolios: A, B and C. Portfolio A consists of the precious metals, portfolio B comprises the base metals and portfolio C is a combination of *all* metals used in this research.

The time frame used spans November 2016 – March 2022. This is specific to the tracking of the upward swing of the post-2000-episode super-cycle and will consequently explore whether said upswing has been exhausted. The expansionary phase of a super-cycle lasts between 10 and 35 years (Erten & Ocampo 2012). The 5-year timeline is divided into three individual periods that will henceforth be referred to as periods 1, 2 and 3. Period 1 spans the roughly 3-year period from November 2016 to February 2020. This is the longest period, but it is also characterised by moderate levels of daily volatility (in comparison with historical volatility levels associated with these commodities). This is the pre-COVID-19 period, deemed to have 'regular', nonvolatile market conditions within the precious metals market with daily volatility levels ranging between 0% and 3%. At this juncture, it is noted that base metals experience higher daily volatility levels during the first period; however, these levels remain more consistent throughout the study, which is illustrated by Figure 2a and b.

The second period covers the COVID-19 pandemic and falls between February 2020 and December 2021 (roughly 2 years). The unexpected negative economic shock (COVID-19) characterises this period. The pandemic is an example of a significant transitory shock within the commodity sector: the focus of this work concerns the ramifications of COVID-19 in metal markets.

Period 2 is underpinned by relatively high levels of volatility (more than 2%) (Figure 2a and b). This provides sufficient evidence regarding the proposition about such periods stimulating business cycles and accompanying super-cycles in the commodity sector (Erten & Ocampo 2012).

The third and final period spans December 2021 – April 2022. This embraces the Russia–Ukraine conflict, wherein the Russian insurgency in Ukraine cultivated the disruption of global supply chain as well as numerous sanctions on the Russian economy (World Bank 2022). The Russian and Ukrainian economies are in aggregate small in relation to the global economy (about 2.2% of global GDP); however, they are significant in some key areas – most notably commodity and agricultural sectors. For example, Russia produces 10% of global palladium; Figure 2a illustrates the dramatic increase in palladium's daily volatility levels since the inception of the conflict during February 2022 (Liadze et al. 2022; World Bank 2022). Furthermore, war is an example of a transitory shock in the metal market. Period 3 is also synonymous with relatively high levels of volatility and is therefore a fundamental feature of Erten and Ocampo's (2012) assertion pertaining to the relationship between periods with high levels of volatility and the upward swing of super-cycles.

Daily metal price data, sourced from third party data providers, were assembled over the period between 2016 and

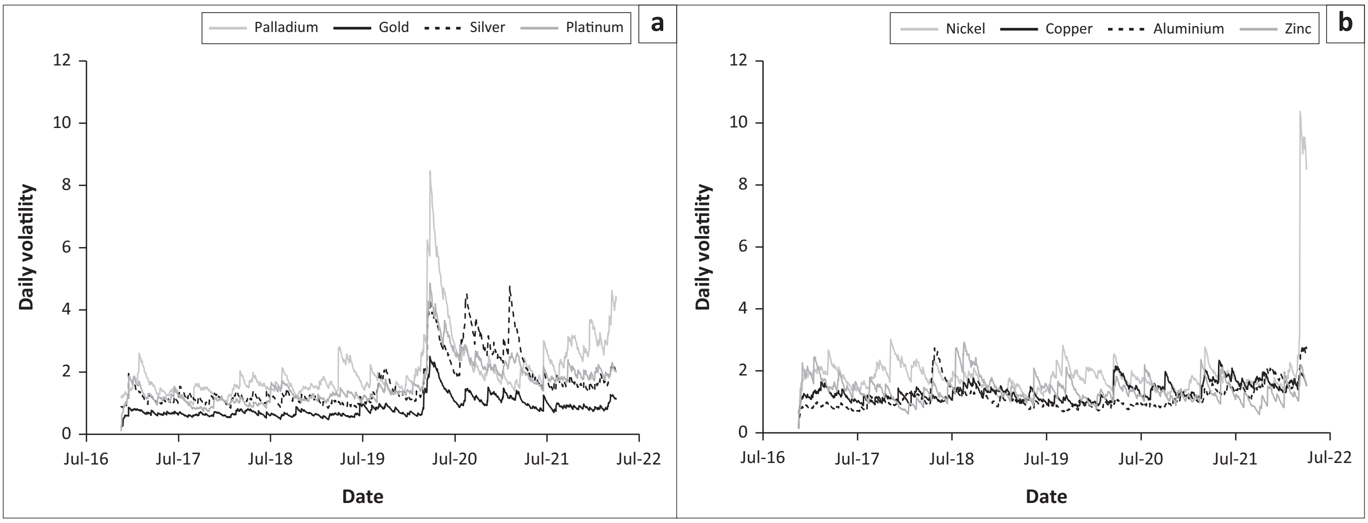

FIGURE 2: Daily volatilities of (a) precious and (b) nonprecious metals (November 2016 – April 2022).

2022. The entire period is medium term; however, each individual subperiod is short term; therefore, daily data are deemed to be appropriate. Daily data provide the means for an accurate representation of the underlying daily returns, which are determined using the historical adjusted closing prices.

Risk-free rates used for portfolios A, B and C are 3-month annualised treasury yields. The 3-month treasury yield was selected because it is the most liquid and has the lowest maturity spread (Corporate Finance Institute 2022). Each period is accompanied by a period-specific risk-free rate. These rates have been calculated by adding the risk-free rates on the first day of the third, sixth, ninth, etc., months within a given period and dividing this value by the total number of intervals. The risk-free rate is 6.6% for period 1, 3.5% for period 2 and 5.7% for period 3 (World Government Bonds 2022).

Methodology

Modern portfolio theory (MPT) optimisation lays the foundation for the generation of efficient frontier portfolios. Efficient frontier portfolios generally detail combinations of constituent assets within a given portfolio which generate a maximal portfolio return at every level of portfolio risk. Portfolios comprise different combinations of metal commodities, wherein the respective daily returns are used in the generation of the frontier. Modern portfolio theory optimisation delivers an efficient frontier where the total expected return is captured on the *y*-axis and the absolute risk on the *x*-axis. The frontiers have been developed upon the assumptions of Markowitz (1952, 1956). The most germane of these assumptions are:

1. Investors are rational and risk-averse market participants.
2. There are no taxes or transaction costs.
3. Assets may be held in any amount (unlimited short selling is possible).

An unconstrained efficient frontier was developed, whereby the full extent of the assumptions above applied. Two investment strategies were selected from the frontiers, namely the tangent portfolio and the minimum-variance portfolio. To assess the methodologies required for the development of the frontiers, it is paramount to discuss fundamental definitions and the mathematical development of efficient frontier construction. This notation was developed by Roll (1992) and advanced by Jorion (2003) for any portfolio consisting of the universe of N available assets. These are listed below. Assume:

$\boldsymbol{q}$: vector of portfolio weights for a sample of N assets
$\boldsymbol{E}$: vector of expected returns
$\boldsymbol{V}$: covariance matrix of asset returns
$\mu = \boldsymbol{q'E}$: expected portfolio return
$\sigma^2 = \boldsymbol{q'V\,q}$: variance of portfolio return

The portfolio must be fully invested, so $\boldsymbol{q'1} = 1$ where $\mathbf{1}$ signifies an N-dimensional vector of 1s.

Merton's (1972) terminology produces the following constraints for the efficient set: $a = \boldsymbol{E'V}^{-1}\boldsymbol{E}$, $b = \boldsymbol{E'V}^{-1}\mathbf{1}$, $c = \mathbf{1'}\boldsymbol{V}^{-1}\mathbf{1}$ and $d = a - \frac{b^2}{c}$.

(Note that Jorion [2003] contains an incorrect definition of c, which has been rectified above).

The definitions above have been outlined and explained and therefore give rise to development of the efficient frontier considering the various constraints. Minimise $\boldsymbol{q'V\,q}$ subject to:

$$\boldsymbol{q'1} = 1 \text{ and } \boldsymbol{q'E} = G \quad \text{[Eqn 1]}$$

where G is a target return (specified by the user). The vector of asset weights for the minimum variance portfolio q_{MV} are established using:

$$\boldsymbol{q_{MV}} = \boldsymbol{V}^{-1}\frac{\mathbf{1}}{c} \quad \text{[Eqn 2]}$$

and the vector of asset weights for the tangent (optimal) portfolio $\boldsymbol{q_{TG}}$ is:

$$\boldsymbol{q_{TG}} = \boldsymbol{V}^{-1}\frac{\boldsymbol{E}}{b} \quad \text{[Eqn 3]}$$

The allocation for any efficient portfolio may be defined as a linear combination of the tangent and minimum-variance portfolios. The vector of efficient portfolio weights is:

$$\boldsymbol{q} = \left(\frac{a - bG}{d}\right)\boldsymbol{q_{MV}} + \left(\frac{bG - \frac{b^2}{c}}{d}\right)\boldsymbol{q_{TG}} \quad \text{[Eqn 4]}$$

Daily data are used in the synthesis of the variance covariance matrices ($\boldsymbol{V}$). Subsequently, a target return level ($\boldsymbol{G}$) is determined wherein the constraints (Eqn 1) dictate the minimum risk requirement ($\boldsymbol{q'Vq}$) by means of altering the weights $\boldsymbol{q}$ such that the addition of all the relative weights equates to 100%. In correlation with Markowitz's (1952, 1956) second assumption, short selling exists within this formulation. If short selling was to be rejected, there would be no closed-form solution to the optimisation problem and hence Excel's solver functionality (or similar) will be applied instead. After determining a group of weight ($\boldsymbol{q}$) at $\boldsymbol{G}$, a different required rate of return may be denoted by $\boldsymbol{G_1}$, for example, which is set and the process repeated until a wide range of possible returns have been considered.

The capital market line (CML) originates at the value of the risk-free on the expected return (*y* axis) and is the tangent line from this point to the optimal (tangent) portfolio on the efficient frontier. The tangent portfolio weights, q_{TG}, are calculated using Eqn 3. The Sharpe ratio is $S_R = \frac{\mu - rf}{\sigma}$ where r_f is the annualised risk-free rate. The optimal Sharpe ratio is found at the tangent line – the point where the CML intersects the efficient portfolio (μ_{TG}, σ_{TG}) only once, derived using $S_R^{optimal} = \frac{\mu_{TG} - r_f}{\sigma_{TG}}$.

Results and analysis

Figure 3, Figure 5 and Figure 6 show the efficient frontiers of portfolios A, B and C during periods 1, 2 and 3. Performance metrics of tangent portfolios situated on the various frontiers are shown in Table 1, Table 2 and Table 3.

Portfolio A

Figure 3 details the portfolio that comprises precious metals (silver, gold, palladium, platinum). Portfolio 1A (P1A) has a Sharpe ratio of 1.9 (Table 1), and the magnitude of this result exhibits the high return, low risk nature of the portfolio. The level of risk at the tangent portfolio is considerable; however, it is associated with strong returns. Overall, the portfolio delivers a robust performance that is characterised by its high Sharpe ratio. These results indicate that precious metals were profitable commodities during this period, and this may point towards the continuation of the upswing of the post-2000 super-cycle (Erten & Ocampo 2012). This notion is reinforced by Figure 1a, as precious metals experienced rising prices throughout the period.

The evidence provided by P1A also correlates to Jacks' (2019) discussion of commodity price series and, more specifically, that boom periods are found within medium-run business cycles. The clear result is that the tangent portfolio yields a desirable output, and this is reinforced by the consistent growth in prices across the board.

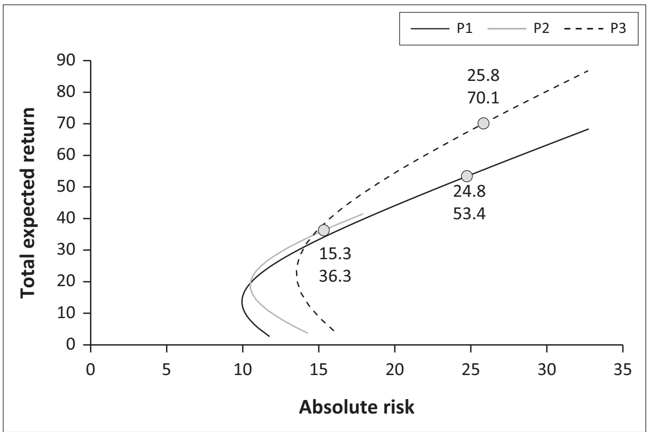

FIGURE 3: Portfolio A (precious metals) efficient frontiers during periods 1, 2 and 3.

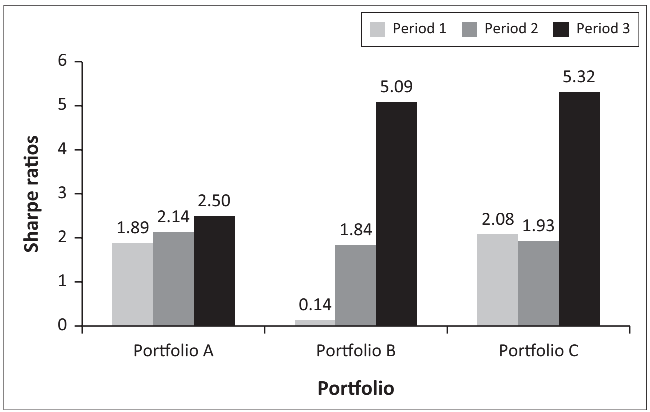

FIGURE 4: Sharpe ratios for the tangent portfolios within the different periods (series).

The second period covers the COVID-19 pandemic and is characterised by high levels of daily volatility. Daily volatility peaks during period 2 are more than double their period 1 counterparts (Figure 2a), a direct consequence of the impact of COVID-19. Figure 1a showcases a dramatic decline in the prices of precious metals upon the inception of the pandemic. However, prices experience a comprehensive recovery and proceed to surpass their prepandemic peaks (Figure 1a). This is somewhat unexpected as the pandemic created a global recession whilst stimulating satisfactory low risk returns in the precious metals market. The initial decline exists in correlation with information provided by the World Bank

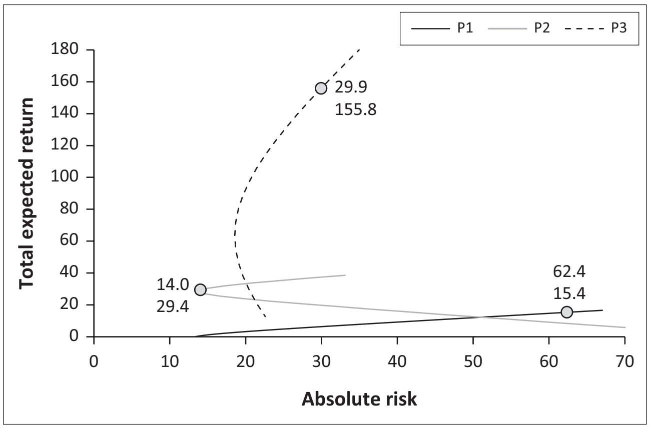

FIGURE 5: Portfolio B (base metals) efficient frontiers during periods 1, 2 and 3.

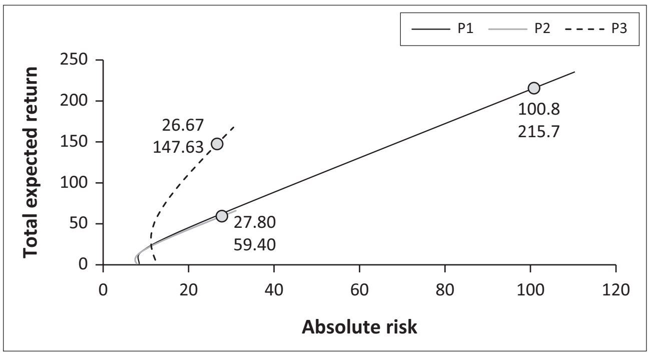

FIGURE 6: Efficient frontiers of portfolio C, a combination of all the metals within portfolios A and B, during periods 1, 2 and 3.

TABLE 1: Summary of portfolio A tangent portfolio performance during periods 1, 2 and 3.

Annualised parameters	Period		
	1	2	3
μ_p	53.3%	36.3%	70.1%
σ_p	24.8%	15.3%	25.9%
SR	1.9	2.1	2.5

TABLE 2: Summary of portfolio B's tangent portfolio performance during periods 1, 2 and 3.

Annualised parameters	Period		
	1	2	3
μ_p	15.4%	29.4%	155.8%
σ_p	62.4%	14.0%	29.9%
SR	0.1	1.8	5.0

TABLE 3: Summary of the performance of the portfolio C tangent portfolios during periods 1, 2 and 3.

Annualised parameters	Period		
	1	2	3
μ_p	215.7%	59.4%	147.6%
σ_p	100.8%	27.8%	26.7%
SR	2.0	1.9	5.3

(2021) regarding the historical depreciation of metal prices upon the onset of recession. However, the subsequent recovery of precious metal prices reinforces Bakas and Triantafyllou's (2020) assertion pertaining to the haven properties of precious metals during recessionary periods. This sentiment is supported by P1A, which consequently delivers the tangent portfolio with the second lowest risk (15.3%) level throughout this study. This sentiment is illustrated by Figure 3 and summarised in Table 1. The efficient frontier of portfolio 2A (P2A) shifts upwards and to the right on the xy-plane. This is indicative of relative increase in returns with a corresponding increase in risk.

The P2A tangent portfolio has a lower return than P1A, but this should be of little concern to traders as the portfolio enjoys a Sharpe ratio of 2.1. The 15.3% decrease in risk at the tangential point in tandem with a higher Sharpe ratio implicates P2A to be superior to P1A. It is important to note that the modest risk level the P2A tangent portfolio is accompanied by a conspicuous increase in daily volatility levels between periods 1 and 2 (Figure 2a). The precious metal portfolio delivered an improved performance in the context of erratic and uncertain global market conditions. These results are consistent with Bakas and Triantafyllou's (2020) assertion regarding precious metals existing as strong hedges in times of prevailing crises. This portfolio's performance suggests that investors and commodity traders alike embraced precious metals on the premise that these assets would successfully bear the brunt of the pandemic.

Period 3 bears notable similarity to period 2, wherein both periods are defined by significant transitory shocks. The Russia–Ukraine conflict precipitates a substantial spike in precious metal daily volatility levels (Figure 2a) at the beginning of the final period. These levels do not surpass the heights of P2; however, the speed and magnitude of the relative increases are noteworthy. Russia produces about 10% of the world's palladium, and this explains the substantial hikes in price and daily volatility (Liadze et al. 2022). The response in the palladium market can be likened to that of the nickel market: prices initially experience dramatic increases, and this is followed by a series of severe fluctuations (Figure 1 and Figure 2). These responses can be attributed to the combination of sanctions, supply chain shocks and Russia's extensive contribution to these markets. Silver, gold and platinum prices undergo moderate price increases upon the inception of the conflict; however, there are no extreme or notable changes in any of these markets. Russia's contribution to the global production of these metals is insignificant: palladium is the driving force behind the increases in both risk and returns in portfolio 1C (P1C). The risk level is 1% greater than that of P1, and the stable performances of silver, gold and platinum prices are responsible for the maintenance of the moderate risk level found within a particularly.

Portfolio 3A's (P3A) efficient frontier shifts upwards and to the right (Figure 3). These details show sizeable increases in both returns and the associated risk level: returns almost doubled whilst the risk level experienced a 10.5% increase at the tangent portfolio. Portfolio 3A comfortably drives the highest returns; however, it also incurs the most risk. Moreover, there is not a substantial difference between the pandemic peak prices and those of period 3; however, there is a significant increase in the Sharpe ratio, with P3A delivering a value of 2.5 (Table 1). This result shows the high returns within the portfolio. The incurred risk is marginally higher than P1 and a further 10% larger than P2 at the tangent point, the implication being that precious metals were successful and secure hedges during the pandemic, whereas the Russia–Ukraine conflict stimulated strong returns in tandem with greater risk and apprehension in the market.

Figure 4 illustrates the steady increase in portfolio A's Sharpe ratios throughout the period.

Precious metals have delivered returns more than 35% at low-to-moderate risk levels throughout, and a positive relationship exists between portfolio performance and periods of transitory shocks.

Portfolio B

Table 2 and Figure 5 exhibit the performances of base metals throughout periods 1, 2 and 3.

Figure 5 illustrates the stark contrast between portfolio 1B (P1B) and P1A. The tangent portfolio reflects an allocation that generates a high-risk, low-return portfolio. The profitability of base metals in period 1 is nonexistent. The portfolio has a Sharpe ratio of 0.1 (Table 2), this being an almost negligible result when compared with the results of portfolio A. The P1B performance is abysmal and points towards the complete exhaustion of the upward swing of the post-2000 super-cycle in the context of the base metal markets. The expansionary phase of a given super-cycle is characterised by strong prices, and P1B is not synonymous with this assertion. This sentiment is affirmed by the period 1 base metal prices depicted in Figure 1b. Portfolio 1B bears greater similarity to Jacks' (2019) assertion pertaining to commodity price series being underpinned by boom or bust episodes during medium-run business cycles.

The portfolio 2B (P2B) efficient frontier is dramatically different to that of P1B. The frontier has shifted upwards, indicative of higher returns. The returns are almost double those of period 1 and the tangent portfolio occurs at a 14% risk level. The growing returns and the 48.4% decrease in risk are bolstered by a robust Sharpe ratio of 1.8. The combination of base metals provides sizeable returns at a low level of risk.

Moreover, base metals enjoy a steady increase in prices during this window (Figure 1b), whereby every metal surpasses their prepandemic peaks.

The volatile market conditions during COVID-19 stimulated an economic recession; however, base metals have prospered. This is an interesting development, and it is augmented by Erten and Ocampo's (2012) assertion relating to periods consistent with high levels of volatility being associated with the upward swings of super-cycles. The price differential between periods 1 and 2 highlights a very interesting development in the base metals markets as the commodity group that had seemingly exhausted the post-2000 super-cycle proceeded to experience prices that surpassed their prepandemic peaks. The nature of the transitory shock and the magnitude of the short-term market fluctuations have synthesised the tangent portfolio with the lowest risk level within the study, and this is complemented by the returns.

The improved performance of base metals during P2 supports Umar et al.'s (2021) assertion relating to base metals possessing portfolio diversification capabilities during the recovery from recession and global crises. The low-risk nature of P2B supports this claim, as base metals provide a secure investment option during a period governed by uncertainty and volatility. There has been a significant improvement on the period 1 results, and this is clearly exemplified by the considerable differential between the Sharpe ratios illustrated in Figure 4 –the P2B portfolio is superior to P1B portfolio in every aspect.

The Russia–Ukraine conflict has had a prominent effect on the base metal markets. This can be attributed to sanctions and supply shocks that are exacerbated by Russia's significant contribution to the global production of base metals. Russia is the second largest producer of nickel (about 7% of global production) and the tenth largest producer of aluminium and copper (approximately 6% and 4%), hence the magnitude of this shock in these markets (Reuters 2022). The portfolio 3B (P3B) efficient frontier moves upward and to the right (Figure 5), which is indicative of a dramatic rise in returns and an almost two-fold increase in risk in comparison to the P2B tangent portfolio (Table 2). The portfolio would have generated a return of 155.8% whilst the risk level is 29.9%, yielding a Sharpe ratio of 5.1. The high value of the Sharpe ratio correlates to Russia's extensive contribution to the global production of base metals, and this is most notably seen in the spikes in nickel price and volatility (Figure 1b and Figure 2b).

The Russia–Ukraine conflict has specific and direct ramifications within the metal market; however, base metals have displayed strong performances throughout periods 2 and 3. These timeframes are characterised by two entirely different transitory shocks, yet the portfolio returns have delivered high returns and impressive Sharpe ratios. Conversely, P1B experienced low returns at an incredibly high level of risk. In addition, P1B also delivered the lowest Sharpe ratio in the study (Table 1). The performances of these portfolios exemplify a strong, positive relationship between the prices of base metals and the transitory shocks discussed in this article. The poor performance during the first period was transformed during the pandemic and culminated in an exceptionally strong portfolio during the war.

Portfolio C

Figure 6 shows the efficient frontiers relating to portfolio C, which comprises all the metals within this study. The portfolio has an even spread of precious and base metals and serves to provide a comprehensive outlook on the greater metal market.

The above analysis implicated precious metals as the superior portfolio during period 1. Figure 6 shows the most prominent feature of the P1C portfolio to be the risk level of 100.8% at the optimal set, as this renders any investment in the P1C portfolio to be largely unfeasible. The counter to this proposition would be built upon the associated return of 215.7% and the Sharpe ratio of 2.1. These two factors illustrate the portfolio's potential; however, this is outweighed by the magnitude of risk. The significant risk level is cultivated in the timeframe that has the lowest levels of daily volatility and contains no significant transitory shocks. Period 1 appears to have the most regular market conditions, yet it has synthesised the portfolio with the highest level of risk within the period under investigation. The potential for high returns is evident, but the risk magnitude suggests that investors and traders alike may have been tentative in their approach to the metal market during the first.

The P1C and P2C (Portfolio 2C) efficient frontiers found in Figure 5 are similarly shaped. The optimal allocation for P2C is 27.8% and 59.4% (Table 3), which is a comparatively lower result than P1C. However, the Sharpe ratio is 1.9, and this displays a differential of only 0.1 to that of P1 (Figure 4). Portfolio C also contains the only example where the period 1 Sharpe ratio is greater than the period 2 results. This is once again a product of the considerable returns associated with the P1C tangent portfolio, but the risk level is undoubtedly the most poignant feature of this portfolio.

The similarity of the Sharpe ratios affirms that both portfolios possess the means to generate strong returns; the clear difference between them is the level of risk incurred. The period 2 risk component is substantially lower, and the connotation of this outcome is the stabilising of metal market conditions during the pandemic. The stabilisation of precious metal prices can be attributed to their attractive hedging attributes, whilst the ballasting of base metals is a result of their portfolio diversification capabilities during the recovery from recession and global crises (Umar et al. 2021). The portfolio maintained a strong Sharpe ratio whilst experiencing an extensive reduction of risk. This sentiment is bolstered by portfolios A and B, as they also saw decreases in risk (most notably in portfolio B) between periods 1 and 2. This is a compelling result and was accomplished despite the dramatic fall in prices (Figure 1a and b) at the inception of the pandemic. Following the initial decline, the market responded positively to the transitory shock and continued to flourish in the COVID-19 market, resulting in a successful portfolio. The P1C portfolio enjoyed the potential for sizeable yet uncertain returns, whereas the P2C portfolio experienced stable and considerable returns.

The portfolio 3C (P3C) (Figure 6) is far superior to portfolios P3A and P3B, as it delivers the highest returns at the lowest risk level. The frontier undergoes a significant upward shift from the P2C frontier – an indication of the substantial returns. There is a minor leftward shift on the *x*-axis as the moderate risk level is maintained. This is an interesting development, as the market risk remains stable during a period defined by renewed volatility and uncertainty. Russia’s substantial contribution to the nickel, palladium, copper and aluminium markets in tandem with the supply-side shocks and global sanctions during the conflict render the growth in returns unsurprising. The success of the portfolio is emphasised by its Sharpe ratio of 5.3 – the largest in the study. The returns in P3C are driven by base metals; however, it possesses a higher Sharpe ratio and lower risk level than portfolio P3B.

Figure 3 and Figure 5 depict very different frontiers whereby the base metals are seen to display irregular behavioural patterns in comparison to their precious counterparts, the implication being that precious metals provide stability within the combined portfolio whilst base metals drive higher returns. Portfolio C exhibits a strong performance during the final period, which is a consistent trend amongst all the portfolios in the study. This result further highlights Russia’s significant involvement in the global production of various metals. The sanctions and supply shocks cultivated an insatiable demand, which in turn has developed the portfolio with the highest returns in the study.

Literature comparison

The results above draw telling similarities with various literature. Erten and Ocampo’s (2012) discussion of the expansionary phase of the post-2000 super-cycle states that the upward swing can last anywhere between 10 and 35 years. Their article also attributes high commodity prices (namely metals) experienced during the 2004–2008 boom as a product of the ongoing super-cycle. Prices proceeded to decline following the global financial crisis but once again recovered on the back of the demand-driven industrial development and urbanisation of China, India and other emerging economies. This once again was deemed to be a result of the expansionary phase of the super-cycle (Erten & Ocampo 2012). This pattern can be likened to the findings of this research.

During period 1, portfolio C exhibited astonishing returns, driven by the performance of precious metals; however, the risk level was more than 100%, a result that would deter most investors (Table 3). Moreover, the first period contains the lowest average prices (Figure 1a and b) in comparison to periods 2 and 3 – this is a consistent result amongst all the metals in this study. All metal prices initially decline at the start of the pandemic; however, they recover and exceed their prepandemic peak prices.

During period 2, portfolio C enjoys a significantly lower risk level and delivers an impressive Sharpe ratio (Table 2). The Russia–Ukraine conflict has created the perfect storm within the metals market, and portfolio C’s results in the final period are a direct indication of this. Therefore, period 1 is characterised by high risks and low prices; however, during periods 2 and 3, returns experienced substantial growth and risk levels were scaled back. This process of comprehensive price recoveries correlates with Erten and Ocampo’s (2012) discussion of commodity prices between 2004 and 2012. Erten and Ocampo (2012) postulate large short-term fluctuations and periods characterised by high levels of volatility to accompany the expansionary phase of super-cycles. To this end, the pandemic and the Russia–Ukraine conflict correlate with this description and further proceed to deliver portfolio performances that would be expected during the upward phase of a super-cycle.

On the other hand, Jacks (2019) argues that commodity price series are products of long-run trends, medium-run cycles and demand-driven boom–bust short-run episodes. The Russia–Ukraine conflict and the consequent supply chain shocks and global sanctions undoubtedly stimulated a demand-driven episode during 2022. The portfolio results during the final period are a product of this event, and this sentiment tends to support Jacks’ (2019) argument. Furthermore, Baffess and Kabundi (2021) affirm that transitory shock-driven medium- and short-term cycles are responsible for 33% and 17% of commodity price variability. The COVID-19 pandemic and the war have initiated transitory shock–driven cycles that have in turn created substantial price variation. The relative performances of the portfolios during periods 2 and 3 render this a plausible assertion, wherein the transitory shocks have generated short-run boom episodes that are clearly exemplified by the returns and Sharpe ratios generated during periods 2 and 3.

Conclusion and suggestions for further study

This article investigates the behaviour of metal prices across three focus periods, wherein portfolios A, B and C proceeded to deliver progressively higher returns from period to period. The results indicate a positive correlation between the prices of both precious and nonprecious metals during the periods of transitory shocks, and this is clearly exemplified by the values of relative Sharpe ratios (Figure 4).

During period 1, the base metal portfolio exhibited negligible returns at a particularly high-risk level. These return levels recovered during the pandemic, but the most notable result was the dramatic decline in the associated risk. This result exemplifies Umar et al.'s (2021) assertion regarding the capability of base metals as a portfolio of diversification device following a recession. Portfolio B proceeds to experience significant returns during the final period, which is clearly illustrated by the incredibly high Sharpe ratio value of 5.1. The most prominent observation in this instance relates to magnitude of Russia's contribution to the global production of base metals (namely nickel, aluminium and copper) (Reuters 2022). Nonetheless, periods 2 and 3 are underpinned by two completely different transitory shocks, and yet portfolios enjoyed higher returns and lower risk in comparison to that of period 1. The poor performance within the first timeframe indicates the potential exhaustion of the upward swing of the post-2000 boom. Portfolio 2C and P3B performances, however, undermine this claim. It is possible that the results in periods 2 and 3 may be products of boom episodes cultivated by medium-run cycles in the market (Jacks 2019). There are insufficient data to make concrete claims regarding the current state of the post-2000 super-cycle or any medium-run cycles based on the results of portfolio B.

The precious metals portfolio details a consistent performance throughout the study. Portfolio A experiences progressive improvements in its Sharpe ratios, but these changes are not as dramatic as those found within portfolio B. The overriding conclusion in this instance is the confirmation of the hedging capabilities of precious metals during periods characterised by economic volatility, which subsequently reinforces Bakas and Triantafyllou's (2020) discussion about precious metals exhibiting safe haven properties. The performance of precious metals during this research provides evidence of the potential continuation of the expansionary phase of the post-2000 super-cycle, and both prices and returns have flourished (Figure 1a and Figure 3). This is best exemplified by the progressive growth in the value of the Sharpe ratio from period to period (Figure 4). These results point towards the continuation of the super-cycle, but they do not provide sufficient evidence to make an outright assertion. However, these results bolster the sentiment pertaining to the positive relationship between metal prices and transitory shocks.

Portfolio C details the combination of all the metals in this research. This portfolio exhibits high returns throughout this study, but the notable changes occur in the associated risk levels. Period 1 incurs a significant risk, delivering a value of 100.8% at the tangent portfolio. The risk level sees a significant decrease during the pandemic, and this is maintained during period 3 (Figure 6). These results implicate the low risk associated with metals during periods of substantial volatility, which exists in correlation with the claims of Bakas and Triantafyllou (2020) and Umar et al. (2021), respectively. Portfolio C delivers the most significant evidence in terms of the continuation of the post-2000 super-cycle, as there are high returns experienced throughout the period, whereby the pandemic and the Russia–Ukraine conflict serve to continue high returns at lower levels of risk.

There are insufficient data to make concrete claims regarding the current state of the expansionary of the post-2000 super-cycle or the possible boom episodes and short-term fluctuations previously cultivated by medium-run cycles (Jacks 2019). Further empirical research is required to maintain this conclusion. In addition, the Russia–Ukraine conflict is ongoing, meaning there are more data that can be collected that will provide increased accuracy regarding the performances of the period 3 portfolios. This work does not consider the impact that fluctuating metal prices may have had on metal price volatility. Metals are not standalone tradeable items, and factors such as the Baltic Dry Index would provide valuable insight pertaining to the further studies based on this research.

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The authors have declared that no competing interest exists.

Authors' contributions

M.v.d.N. was responsible for conceptualisation, writing, analytics and visualisation. G.v.V. was responsible for supervision, analytics, visualisation and supervision.

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