Time and frequency price linkages between the futures markets of silver and platinum: A Wavelet Local Multiple Correlation approach

by

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A thesis submitted in fulfillment of the requirements for the degree of

Master in Economic Analysis

in

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Abstract

This study examines the dynamic relationship between silver and platinum daily futures prices, from 2 February 2018 to 2 February 2025, covering the period of the COVID-19 pandemic. Both metals hold a dual role as investment assets and industrial inputs, making their prices vulnerable to macroeconomic shocks, supply-demand imbalances, and industrial shifts. Data for the analysis were obtained from Investing.com. The Wavelet Local Multiple Correlation (WLMC) method, supplemented by wavelet coherence, has been applied to capture co-movements and volatility persistence across multiple time-frequency scales. The results reveal a persistently positive but time-varying correlation. High frequencies indicate moderate and unstable co-movement, whereas medium-term horizons present a stronger relationship with cyclical patterns throughout the pandemic. Low frequencies exhibit the most consistent and strong co-movement, underscoring a structural interdependence between the two markets. This work also focuses on volatility dynamics, revealing that the correlation between the two metals in medium and long horizons peaked during the pandemic, with a partial decoupling following in the post-pandemic period. Dominant heatmaps are used to visualize the most dependent variable in their relationship, revealing platinum's dominant role across most time scales, highlighting an asymmetric dependence. By focusing on silver-platinum linkages, an area less explored in prior research, this analysis provides novel multiscale evidence of their time-varying co-movements, volatility spillovers, and platinum's asymmetric leadership.

Keywords: Silver, Platinum, Price linkages, Wavelet Local Multiple Correlation (WLMC), Wavelet Coherence, Safe-haven assets, Precious metals Co-movement, Volatility, Time-frequency analysis, Non-linear analysis, Multi-scale correlation.

1 Introduction

Precious metals hold a unique position in global markets. They fulfill a dual role, as traditional investment assets and as vital resources for industrial and technological uses. Among them, silver and platinum are distinguished for their complex behavior, as they combine monetary value with strong industrial relevance. Their hybrid character exposes their prices to an extensive variety of shocks, from financial instability and macroeconomic uncertainty to supply chain and geopolitical risks. In recent years, exogenous shocks have disrupted silver and platinum prices, showing that despite their safe-haven role, they remain vulnerable to industrial cycles. In particular, the COVID-19 pandemic brought unpredictable challenges to precious metals markets. Disruptions from mine shutdowns, workforce shortages, and trade restrictions caused severe supply constraints, combined with uncertain shifts in demand patterns. During 2018-2024, the global silver market suffered significant changes caused by the pandemic and the following recovery. In 2020, global mine production declined to 783.8 Moz, while the previous years had not fallen below 850 Moz, and only modestly recovered to 819.7 Moz by 2024. At the same time, industrial demand follow a raising ratio, recording 680.5 Moz, led by photovoltaics and electronics. The physical investment demand note a rose to 28.1 Moz, while until 2024 fell to 190.9 Moz. These dynamics correspond to a recurring annual deficit of approximately 800 Moz over 2021-2025. Institute (2025).

Similarly, the platinum market has also been influenced by the COVID-19 pandemic, as supply interruptions caused significant structural imbalances. According to data from the World Platinum Investment Council (2025), a sharp decrease in global platinum production was observed in 2020, due to mine shutdowns and smelting lags hitting producing countries, especially South Africa, which derives around 70% of the world's platinum. Notably, total refined output dropped to 5.52 Moz, marked as the lowest supply levels over the past decade. Reduced vehicle production led to a decrease in demand from the automotive sector, while the decline in supply was even more significant, causing a market deficit of 0,355 Moz. In 2024, refined output has started to recover to 7.3 Moz as structural shifts in recycling and supply kept the market tight. From an investment side, by 2020, platinum attracted interesting investors, increasing investment physical flows 0,63 Moz, while in 2024, bas and coin demand reached only 0.19 Moz.

At the same time, economies make efforts to adapt new technological and environmental techniques. The transition required greener priorities, including photovoltaic installations, battery systems, and hydrogen fuel-cell technologies. All of these rely on silver and platinum as the main input. The price behavior of these metals shaped not only their role as a monetary hedge, but also their contribution to adapting sustainable technology and industrial innovation. Examining how silver and platinum behave during times of market stress can help investors and policymakers improve price forecasts and manage risk effectively. Futures markets also play a critical role in the precious metals sector. Such derivative markets connect traders who aim to benefit based on expected price shifts, with buyers who seek secure future supplies and costs. The effectiveness of mechanisms in supporting price discovery and stabilizing markets relies on price linkage and volatility through metals. As silver and platinum have attracted investors' attention, academic research focuses on gold as the primary precious metal in the literature. However, a clear research gap remains regarding the dynamic relationship between silver and platinum, particularly during crisis periods.

Figure 1 displays the smooth and stable price path of gold, confirming its role as a safe-haven asset during turbulent times. In contrast, silver and platinum exhibit higher volatility and sharper price shifts to external shocks such as COVID-19. The observed divergence differentiated their patterns from gold's and pointed out the necessity of further investigation between the two metals.

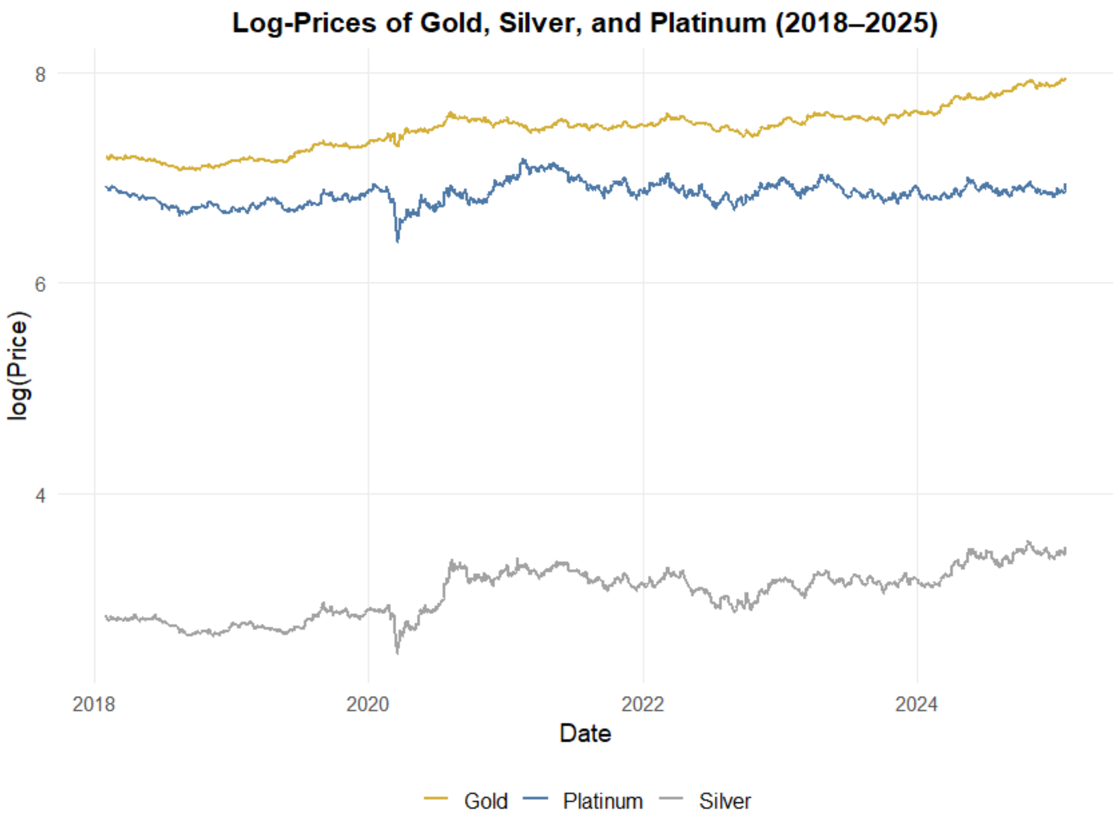


Figure 1: Price movements of gold, silver, and platinum (2018 - 2025). While gold remains relatively stable, silver and platinum exhibit greater volatility.

Compiled by author.

[1]

[2]

In response to these challenges, this study aims to examine silver and platinum in isolation and extend the existing literature by examining their dynamics in depth. The analysis covers the period from 2 February 2018 to 2 February 2025, a time frame noted by sudden structural breaks in commodity markets. In recent years, new techniques have been developed to better understand the way commodity prices co-move across different time horizons. Fernández-Macho (2012) introduced a flexible approach in this area, the Wavelet Multiple Correlation (WMC) method.

[1] Data for gold, silver, and platinum were collected from `https://www.investing.com/`

[2] For visualization purposes,Figure 1, Figure 6 and Figure 7 were compiled in log-prices. Although all statistical analysis, including normality tests, correlation, and WLMC method, are constructed by log-returns.

However, its time-localized expansion as Wavelet Local Multiple Correlation has been applied first by Fernández-Macho (2018). In contrast to traditional methods, WLMC captures both the timing and the scale of correlation during turbulence periods. Martínez et al. (2018) applied this method to examine price relationships among crude oil and six refined petroleum products over a pre-2017 sample, indicating asymmetric and evolving dependencies in different time scales. Polanco-Martínez et al. (2020) has employed the WLMC method to capture the correlation between various North Atlantic climate variables such as sea surface temperatures (SST), tropical cyclone counts (TC) and others.

In addition, Bouri et al. (2023) used WLMC to study major commodities such as crude oil, gold, copper, and wheat, revealing instability in high frequencies and stronger correlation in low frequencies. Similarly, Shah et al. (2022) used this approach to investigate the dynamic relationship between oil and carbon emissions during the pandemic and energy innovation. Their findings show that in low frequencies, CO2, and the global energy innovation index present a pronounced asymmetric negative relationship. While the WLMC approach has been used for such commodities, its application in precious metals, particularly the silver-platinum linkage, remains limited. This study aims to fill that gap by applying the WLMC approach to analyze how silver and platinum futures interact in a dual dimension: over time and across different time scales. Particular focus is placed on the COVID-19 period to examine in more detail how major global shocks have influenced their dynamic interaction.

The structure of the study is as follows. Section 2 describes the relevant academic literature on price dynamics and methods used among precious metals. Section 3 presents the data, including figures and descriptive statistics, and unit-root tests for silver and platinum. Section 4 introduces the empirical methodology with WLMC as the main framework and the results. Section 5 provides a relative discussion, and Section 6 summarizes conclusions.

2 Literature Review

Commodity markets are organized by two main mechanisms: the spot market and the futures market. The spot market refers to an agreement between buyer and seller with immediate delivery, setting prices on current supply and demand. In the precious metals market, spot trading is necessary for consumers who need to buy "on the spot" such as jewelers, industrial manufacturers, or investors. Spot prices are characterized as a reference point for derivative products, and they contribute to direct liquidity and transparency. Factors such as political instability and seasonal shifts make spot transactions vulnerable to short-term shocks as they demand physical settlement.

The futures market functions through standardized contracts. These contracts allow participants to agree on prices and delivery dates in advance, using standardized exchange-traded contracts. This approach provides an effective way to handle risk management and support stakeholders to diminish uncertainty in their operations Hull and Basu (2016). When unpredictable price swings occur, fixing prices for future transactions hedges against them. Therefore, the hedging role is one of the advantages of futures markets. Futures prices can function as forward-looking indicators: they absorb information about production costs, demand conditions, and in general for macroeconomic effects, and then they lead spot prices by sending signals. These signals are related to market expectations, price discovery, and market efficiency.

2.1 Silver

Several studies have investigated silver's price behavior within the commodity and financial system. Cortazar and Eterovic (2010), use a modified multi-commodity pricing model that includes both non-stationary and mean-reverting components, aimed to explain silver's long-term dynamics related to oil futures. The authors used a framework that shows both common macroeconomic and commodity shocks. Their empirical results show that the correlation between silver and oil is weak, but still, related commodities can help to improve long-term price shifts, particularly when silver is not stable in price levels.

Similarly, Tessmann et al. (2024) used a network econometric approach based on Diebold-Yilmaz spillover index and complex network metrics estimation to investigate interactions among 12 commodities, including silver and platinum, and emphasized the strong connections with the gold and energy markets. Their approach allows for time-varying conditional correlations and identification of key transmission into the metal system. Their results suggest pronounced volatility connectivity between silver and gold. Their findings support the notion that during uncertainty, precious metals, especially silver, can act as hedge.

In financial markets, emerging assets and global risk factors affect silver's behavior. Yaya et al. (2022), applying CCG-VARMA GARCH model to analyze return spillovers from Bitcoin to silver (and gold). Their methodology aims to capture both own-market effects and cross-market transmission, allowing for the identification of dynamic interdependence. The findings show no significant return spillovers; however, they reveal bi-directional volatility spillovers, indicating that silver can be a transmitter and receiver of financial uncertainty.

Chiang (2022) using DCC-GARCH model to examine gold and silver's safe-haven characteristics. Their results shows that silver hold a negative relationship with equities with a hedging role with statistically insignificance during COVID-19. However, silver present a weaker role as a safe haven asset compared to gold.

Beyond its role as a financial asset, its demand has increased significantly since the pandemic. It is widely used in electronics, solar panels, electric vehicles, and 5G infrastructure. The Silver Institute (2023) illustrates that only the photovoltaic applications will consume up to 120 million ounces of silver annually by 2030. The study of Złoty et al. (2024) noted that the dual nature of silver as investment and industrial asset. They capture a structural perspective on the supply of silver and its vulnerabilities, combining market data with ESG policy trends. Their analysis highlights the constraints imposed by environmental regulations on silver mining, especially in producing countries. Their conclusions show that supply shortages are driven by the challenges in recycling efficiency.

Vigne et al. (2017) provided a comprehensive survey related to the financial economics of white precious metals. They used cointegration tests and VAR modeling. The analysis reassures that silver reacts positively to expansionary monetary policy, particularly through channels such as inflation. The co-integration results show a long-run equilibrium relationship with economic variables. Lastly, the VAR model shows that silver's responses to macro shocks are both asymmetric and volatile, due to its long-term role as a store of value.

Živkov et al. (2022) implemented Markov-switching GARCH models to analyze the degree of volatility between the spot and futures market in silver. They introduced the scenario of "heatwave" and "meteor shower" effects to diversify the intra- and inter-market spillovers. Their findings show that the futures market leads the spot market during high volatility due to increasing liquidity and smoother information flows.

Robinson (2024) conducted a structural VAR (SVAR) model to capture silver's reactions to macroeconomic shocks - combined with oil and gold prices, interest rates, and exchange rate fluctuations. Contemporaneous linkages are captured through the strategy, making it more possible to disentangle structural shocks. When monetary policy tightened, silver prices noted a sharp decline at first. However, silver can be characterized more as a "partial safe-haven" as it doesn't follow a consistent way in economic uncertainty.

Khan et al. (2025) applied a Quantile Vector Autoregressive (QVAR) connectedness model in the frequency domain. By integrating wavelet coherence analysis, the study focuses on the price co-movement between silver and other assets. Their analysis points out that silver is a net receiver of shocks in the upper quantiles (0.95), noticing the sensitivity during stress episodes. In contrast, its interaction with other markets had a limited effect, confirming that the behavior of silver does not follow a consistent pattern.

Solt and Swanson (1981) on their earliest papers investigates the efficiency of silver markets around the information they have. They use speculative trading models and empirical tests on pricing patterns to illustrate that silver markets tend to deviate from random walk behavior. According to the authors, the deviation drives to inefficiencies, which stem from speculative dynamics and some non-fundamental factors such as sentiment and manipulation.

Figuerola-Ferretti and McCrorie (2016) provides further insight with bubble detection methodology to analyze the price behavior of precious metals for the period of Global Financial Crisis. Their findings showed that silver price deviations were driven mainly by the launch and flows of Exchange-Traded Funds (ETFs) and less by the financial crisis during 2000-2013.

2.2 Platinum

Platinum's market behavior is principally driven by its industrial use rather than its role as an investment asset. Platinum belongs to the platinum group metals (PGMs) and its main role is in high-tech and environmental applications such as catalytic converters, medical devices, and electronics, thanks to its catalytic efficiency and corrosion resistance Wilburn and Bleiwas (2004). These applications set platinum to be highly sensitive to global industrial cycles and macroeconomic developments.

In contrast with gold and silver, platinum's supply is highly concentrated due to the fact that over 70% of global production originates from South Africa, followed by Russia and Zimbabwe Li et al. (2023). Using global supply chain mapping and regional production statistics, they quantified how geopolitical and logistical risks are created from the geographic imbalance. Their analysis revealed that not only are mining and refining managed by a minor number of key players. This drives the supply chain to an increasing susceptibility to external shocks.

Hence, due to limited geographic concentration, platinum's market is exposed to geopolitical risks and logistical disruptions. Rasmussen et al. (2019) using a dynamic material flow analysis (MFA) with future demand scenarios, focused on bottlenecks in the worldwide supply chain. They also analyze labor strikes in South Africa which cause issues in global production. Scenarios showed that the market is sensitive due to the constrained supply.

Recycling also faces resistance. The World Platinum Investment Council (2024) and Johnson Matthey (2024) reveal to their reports that over the last years noted lower scrappage rates and extended vehicle lifespans. Reduced recycling drive due to limited availability of platinum from end-of-life converters, as almost 2% of supply comes from recycling. As a result, this source remains constrained, particularly due to slow automotive turnover and postponed ESG-related regulations. Recent studies in recycling technologies suggest a change in platinum.

Sverdrup and Ragnarsdottir (2016) further examines recycling inefficiencies using system dynamics modeling. Their approach includes simulation via STELLA software using differential equations, which were solved through Rung-Kutta method to capture relationships among mining investment, recycling capacity, and market demand. The results of the model appear to show feedback delays, cyclical shortages, and slower production. They also highlight the sensitivity of platinum to time lags in policy and supply expansions, which can create price swings during a crisis.

It is important to refer further the financial perspective of platinum. Earlier Robinson (2017) applied a structural vector autoregressive (SVAR) model to investigate platinum's reactions to macroeconomic variables (i.e., interest rate shifts, oil prices, and GDP growth). The findings show that platinum prices tend to increase when GDP OECD is increasing, while when shocks to interest rates occur, short-term spikes are observed, which in turn lead to long-term stabilization.

Later Zhang et al. (2022) applied the traditional ARCH framework to detect volatility clustering in the platinum market during the coronavirus, combined with asymmetric responses to external shocks. Their results indicated that platinum tends to respond negatively to the pandemic and to present asymmetry patterns.

The gold-platinum ratio is also an indicator that reflects the financial use of platinum. Huang and Kilic (2019) using a regression-based asset pricing model, analyzed the strength of the ratio in investor exposure to tail risk and market stress. They reached the following result: the increases in the gold-platinum ratio are associated with risk aversion, as investors during stress periods tend to move their holdings from platinum to gold. At the same time Malik et al. (2024) applied cross-sectional regression to examine the gold-to-platinum ratio and U.S active equity mutual fund flows. Their findings highlight that funds which are sensitive to the GP ratio attract more inflows thanks to a hedge to economic uncertainty. These results characterize platinum as a less appealing safe-haven asset due to its pro-cyclical nature.

Vochozka et al. (2022) provides further insight about platinum investment features using deep learning neural networks. Their analysis shows the possibilities of platinum to hold the investment character and their results confirmed that it can be a store of value and a "wealth multiplier" assuming that market conditions are stable.

2.3 Silver and Platinum

Duran et al. (2024) provides further insights into the volatility transmission mechanisms, related to financial markets and precious metals interactions. They employed both TGARCH and DCC-GARCH models on how volatility from S&P 500 spills over into gold, silver, and platinum prices. Their findings show that silver and platinum exhibits increased co-movement with equities during crisis. Platinum presents stronger susceptibility to volatility spillovers and a higher correlation with the S&P 500 compared to silver.

In recent years, have focused on the complex and non-linear relationship between spot and futures prices in precious metals. In the case of silver and platinum, their asymmetric reactions to shocks and the non-linear price adjustments have attracted the interest of many researchers. Although both precious metals behave differently as silver tends to be more speculative and reactive, while platinum behaves more fundamentally and reacts more in pro-cyclical trends.

Batten et al. (2010) used a Vector Autoregressive framework (VAR) followed by a block of exogeneity restrictions and conditional volatility models to capture cross-market volatility among silver, platinum, gold, and palladium. Their analysis shows that neither of these metals can stand as a homogeneous class. Silver volatility is not led by macroeconomic factors rather by volatility in other precious metals.

Melas et al. (2024) adopted a systematic review of volatility spillovers in commodities, analyzing studies that used econometric models such as DCC-GARCH, BEKK-GARCH, wavelet coherence, and copula models. The conclusion shows that silver has strong volatility interactions with other precious metals. On the other hand, platinum behaves more as a volatility receiver.

Charles et al. (2015) analyzed the weak-form efficiency of precious metals within the Adaptive Market Hypothesis framework, using automatic portmanteau and variance ratio tests. Their findings show a decline in silver's return predictability over time, suggesting improved market efficiency. However, platinum did not exhibit the same behavior in efficiency as gold and silver due to its heavy dependence on industrial demand, which makes it more vulnerable to economic conditions.

Wang et al. (2023) studied the effects of oil price shocks on silver and platinum across multiple market conditions. Their methodology is based on quantile regression, and their results reveal that oil includes in a positive way, precious metal returns during low-quantile periods. Thus, both metals protect against inflation, but silver's responsiveness was stronger. They also showed that when the U.S dollar depreciated, returns on silver and platinum usually increased, although silver presents a sharper reaction in extreme quantiles, exhibiting sensitivity to currency volatility. Mohamed and Mohamed (2023) analyzed the dynamic relationship between precious metals, crude oil, and the exchange rate using co-integration analysis and variance decomposition. Their results show that between these markets, there is a stable long-run equilibrium, although it is weaker in the short run. Platinum tends to exhibit the highest positive correlation with oil prices, thanks to its industrial dependence, while silver prices are synchronized more with gold and less with oil.

Similarly, to the pronounced results, Arif et al. (2019) analyzed the non-linear linkage between oil and prices and, in general, white metals -silver, platinum, and palladium, using quantile - on - quantile (QQR) regression method. Their methodology led them to detect asymmetries across different market conditions by examining the influences. For example, how specific quantiles of oil prices affect specific quantiles of metal returns. They also found a strong positive relationship between these metals and oil prices in the lower quantiles. They highlight the existence of co-movement in stress periods, while at higher quantiles there weaker correlation was observed. For silver, apparently, the relation with oil tends to be mixed and less stable, combined with positive interactions in high oil price conditions but a negative correlation elsewhere. Later in their study, they applied ARDL model, which presents short-term dynamics but no long-term cointegration.

While econometric approaches give us valuable insights about the price dynamics, the directional causality of silver and platinum, and their reactions to external shocks, they often overlook the structural properties that shape real-world price movements. Building on the existing literature, this study expands the discussion by incorporating structural aspects of precious metals, emphasizing the role of Exchange-Traded Funds (ETFs), margin requirements, and institutional trading behavior. ETFs such as the iShares Silver Trust (SLV) and the Platinum ETF (PPLT) enhance liquidity and help investors to observe metal prices without engaging directly in futures. The most common futures contracts on COMEX and NYMEX for silver and platinum, standardized in quantity and delivery, contribute to structuring market expectations, while marginal requirements assure stability but present rollover risk for long-term positions Hull and Basu (2016). Thus, the constrained share of silver futures results in physical delivery (less than 2%), while platinum has a higher settlement ratio, revealing its stronger industrial hedging role Silver Institute (2023). These structural aspects enrich the economic literature by showing how institutional mechanisms form volatility transmissions and affect price behavior.

3 Data

The data are daily observations for future prices of silver and platinum covering the period from 02 February 2018 to 02 February 2025. All prices are expressed in US dollars per troy ounce (USD/oz), respecting market conventions. Historical data for market balance (supply-demand) were sourced from `https://silverinstitute.org/all-world-silver-surveys/` and World Platinum Investment Council (2025) - WPIC, which draw on estimates from Metals Focus (2024) and SFA Oxford. The estimate for 2025 describes a forecast based on current industry expectations.

3.1 Supply-Demand Analysis

Figure 2 and Figure 3 show the market balances for both metals, reflecting the different reactions to the pandemic.

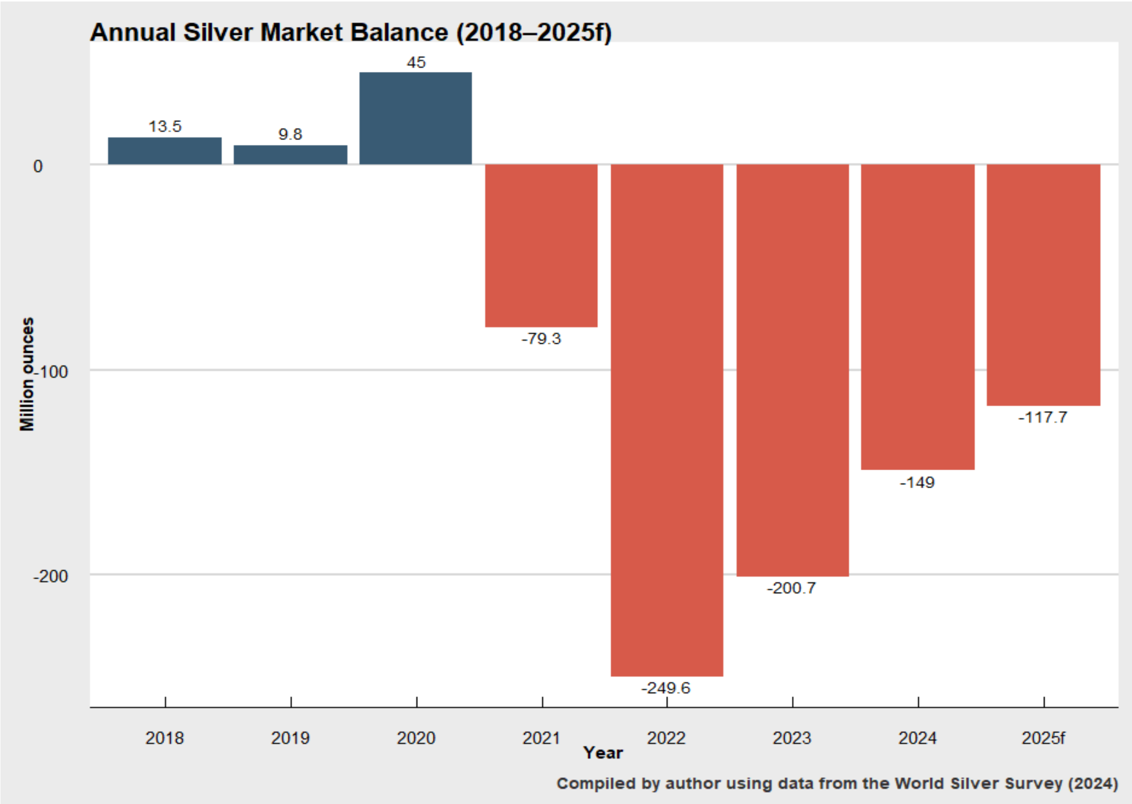


Figure 2: Deficits have started after the outbreak. In recent years major improvements have been noted with shortages decreasing.

[3]

Figure 2 illustrates the market balance for silver during 2018-2025. Between 2018 and 2020, the silver market presented moderate surpluses. Moreover, during 2018-2019 the decrease in surplus wasn't significant. In 2020, a major increase from 10 million ounces (in 2019) to 45 million ounces (in 2020) was noted. Global mine production dropped by 6%, while recycling starts to rise by 7%. However, jewelry and silverware demand collapsed, while physical investment (bars, coins) has increased. The Figure 4 also shows that, before the outbreak, silver wasn't significantly appealing to investors, while from 2020, silver's investment demand increased steadily. Investors use silver as a safe-haven asset amid financial uncertainty and low interest rates. The excess supply is absorbed by the increasing investment demand, preventing the market from a larger imbalance until 2021. The reduced investment

[3]Data were obtained from `https://silverinstitute.org/wp-content/uploads/2025/04/World_Silver_Survey-2025.pdf`, sourced from Metals Focus (2024).

demand is offset by the increasing investment demand Focus (2021).

Therefore, in 2021, the silver market changed from surplus to deficit, recording a negative balance of 79 million ounces. This sharp decline introduces the critical mismatch of the supply-demand balance, driven by the post-pandemic recovery in industrial activity, especially in the sectors of photovoltaic and electronics. However, demand recovered faster than mining operations, as they still deal with labor and transport issues. Later in 2022, the deficit deepened to 250 million ounces, rendering it the largest debt silver market marked in the last six years (the outbreak of the Russia-Ukraine war contributed negatively to worsening the deficit. The continuously increasing demand, combined with constrained supply caused by structural disruptions from the pandemic, holds the deficits at high levels, while the investment demand reached its peak at 337.7 Moz as we expected - due to its safe-haven role. Focus (2022) Focus (2023).

The last two years, in 2023-2025 (including 2025 as a forecast), the silver market remained in deficits, but has started to be reduced. The debt was around 49 million ounces fewer than the previous year, meaning that there was a partial stabilization of supply chains and recovery in mining output. The industrial demand, which is driven especially by photovoltaic installations, remained at high levels. From 2023, investment demand diminished as the economic cycle was more stable. Although in 2024, the deficit narrowed further at 149 million ounces, the forecast for 2025 anticipates the shortfall to diminish even more to 118 million ounces. Despite the demand continuing to exceed supply, the silver market has started a rebalancing process. In this area, investment demand - especially in the US - is falling sharply, reaching almost the pre-pandemic level, reaching 183 Moz. Focus (2023) Focus (2024). Overall, the silver market benefits from the strong dependence on both the industrial and investment sectors because even in turbulent periods, when the industrial demand has fallen, the increasing investment demand keeps prices at high levels.

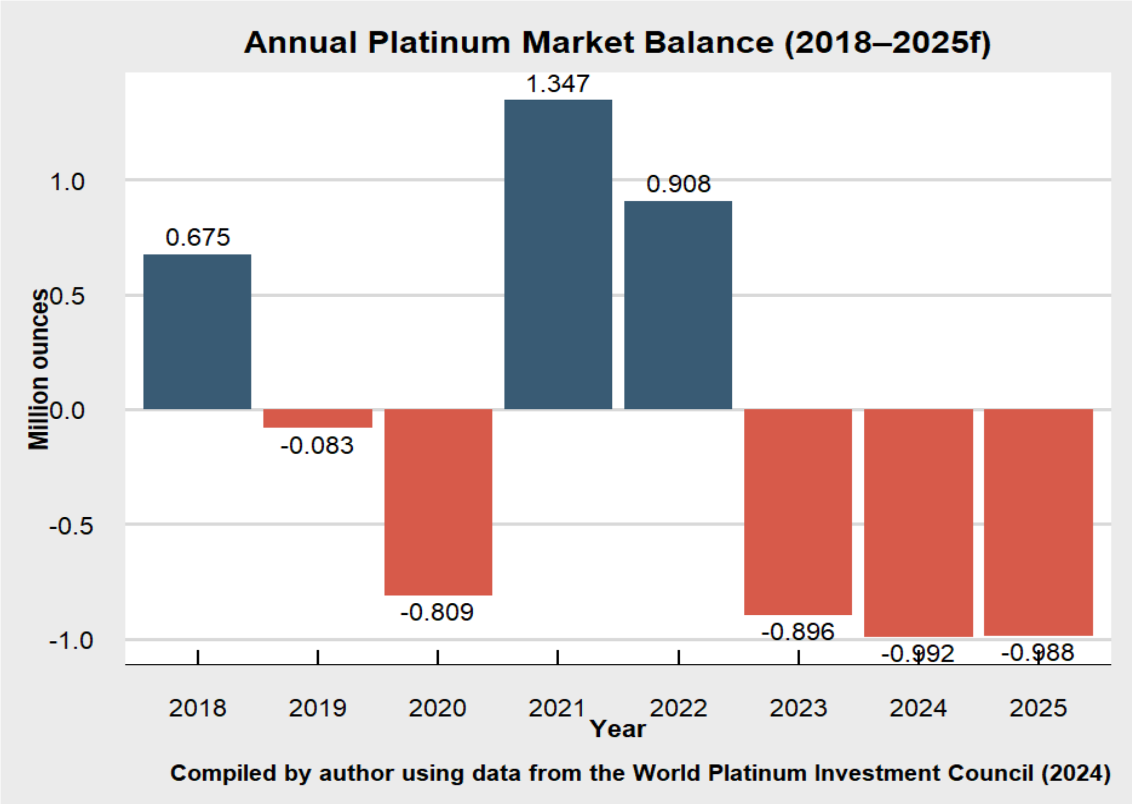


Figure 3: After a brief surplus in 2021-2022, the platinum market shrank into deficits, underscoring structural tightness.

[4]

Figure 3 similarly illustrates the annual platinum market balance. In early 2018 platinum market noted a surplus of 0.675 million ounces (Moz), while from 2019, deficits were noted. As shown, the market noted a minor deficit of -0.083 Moz in 2019, caused also by the disruption in mining, resulting in the already constrained production being tightened. The Figure 4 reveals that the investment demand of platinum remains lower than that of silver and is stable before the outbreak.

In early 2020, the debt deteriorated with a steep decline of -0.0809 Moz, which was also driven by mine shutdowns, labor constraints, combined with the increasing automotive demand. At the same time, the investment side presents a sharp upward trend despite its role as an asset that was undervalued compared to gold or palladium

[4]The data used in the figure were collected fromWorld Platinum Investment Council (2025) (which sourced by SFA Oxford (20142018), Metals Focus (2024))

Council (2021). Notably, in 2020, the investment demand peaked at 0.593 million ounces.

In 2021, an important shift was observed, owing to the beginning of the recovery phase. The surplus is larger than the pre-pandemic period, reaching 1.347 million ounces, as mine supply recovers while the one-off release of ACP inventories creates a rebound in industrial demand. Despite the low levels of mined output, this inventory helps the supply levels. Thus, the petroleum refining, chemical, and glass sectors strengthen even more the surplus Council (2022). Simultaneously, the investment demand follows a downward trend for the next few years, indicating the reduced interest for investors.

Later, in 2022, a surplus remained with a slight decline, which was observed at 0.0908 Moz as industrial demand started to adapt, owing to the automotive sector, while mine supply still dealt with power outages and labor disruptions. At the same time, investment flows have been decreasing even more, reaching values near 0.259 million ounces. These factors tightened the market balance before deficits appeared again in 2023 Council (2023).

Moreover, from 2023 onward, the platinum market shifted into deeper deficits as industrial demand remained high but mine supply was constrained in South Africa and Russia (due to power shortages and labor limitations). Besides that, automotive and jewelry continue to add further pressure on the supply. In addition, investment demand becomes weaker, reducing one of the supportive elements of the balance. These conditions explain the larger deficits of -0.896 Moz in 2023 and -0.996 Mon in 2024. The forecast for 2025 shows that the market will remain in deficits, but no major and sharp decline is expected (towards -0.966). The narrow and slight decrease reflects improvements in supply, but demand is anticipated to remain at high levels. Council (2024) World Platinum Investment Council (2025).

Since investment demand plays a key role in the market balance of both metals, acting as a balancing factor against industrial volatility, it is important to illustrate their pattern over the years separately. The following figure demonstrates the evolution of physical investment in silver and platinum, with their peaks marked in each year. The physical investment refers to the total demand for bars and coins purchased by retail and institutional investors. Exchange-traded products (ETPs) are excluded from this illustration. It is important to note that the scale of physical investment in silver exceeds, showing its lower price and broader role as a safe-haven asset, while platinum investmentrole remains limited.

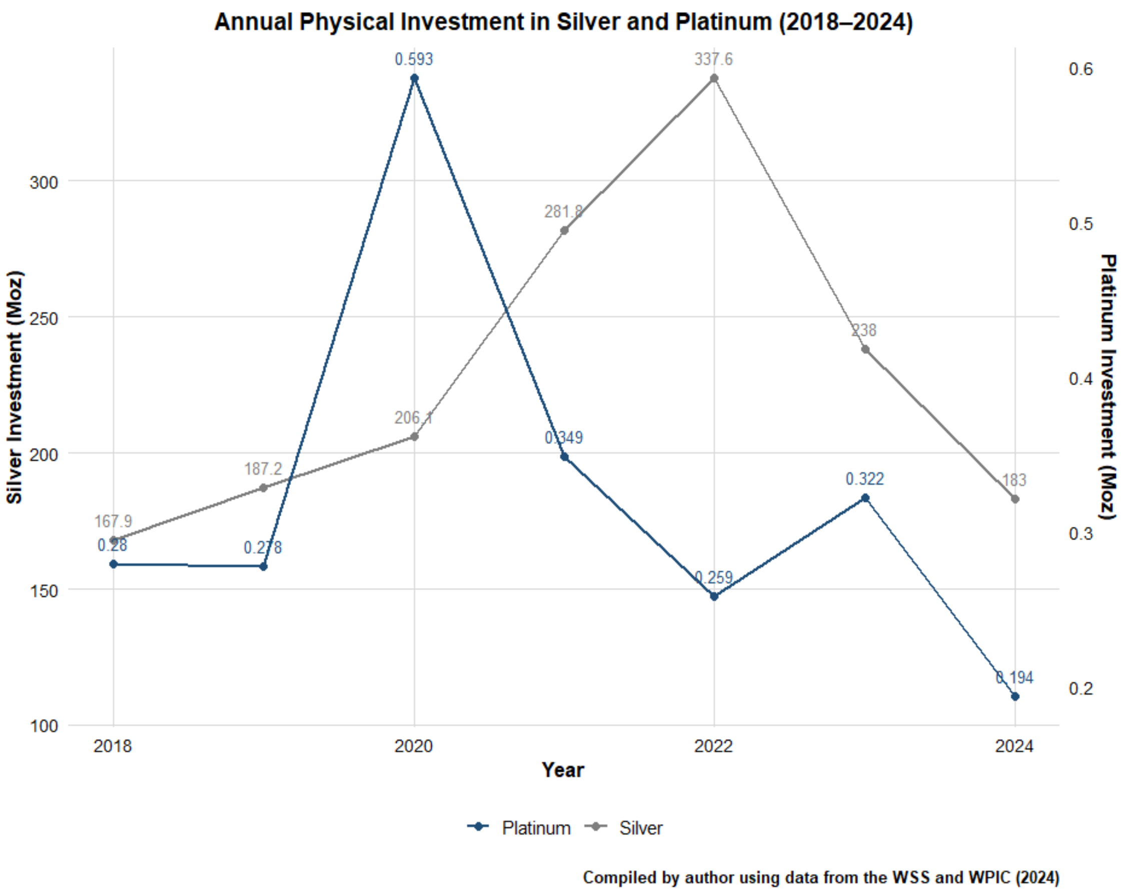


Figure 4: Both metals illustrate a similar pattern on the investment side, with their peaks varying due to their different dependence on external demand factors.

[5]

[5]Platinum's data and all investment values are expressed in million ounces (Moz). Platinum values were drawn from World Platinum Investment Council (2025) in thousand ounces (koz) and were converted to Moz by dividing each value by 1,000.

3.2 Descriptive Statistics

Table 1 provides descriptive statistics for the log-returns for both metals to analyze their average behavior, variability, and distributional characteristics.

Table 1: Descriptive statistics for log-returns of Silver and Platinum

Statistic	**Silver**	**Platinum**
Minimum	-0.11603	-0.12904
Maximum	0.08889	0.09931
Mean	0.00032	0.00002
Median	0.00042	0.00038
Std. Dev.	0.01780	0.01748
Skewness	-0.40774	-0.25750
Kurtosis	8.45782	7.51587
Shapiro–Wilk test (W)	0.926	0.964
	($<$0.001)	($<$0.001)

Note: p-values in parentheses.

Log-returns are used in financial analysis as they provide additional information. First, they normalize the data across assets of different scales, allow for time-additive characteristics, and improve modeling with standard statistical methods. The most important part is that log-returns properly capture the relative day-to-day changes in value, as it is necessary for evaluating market risk and volatility and investigating further the statistical impacts of financial time series.

The minimum and maximum log-returns for both metals reveal information about the size of extreme daily price swings. Silver marked a daily loss of -11.6% and gain of 8.8%, while platinum experienced -12.9% and 9.9%. These outliers reflect the reaction of the two metals to episodes of heightened uncertainty and market stress, such as COVID-19. Such extreme return values shape the distribution, resulting in high kurtosis, which is discussed later.

The mean daily log-returns provides information about the direction and the intensity of the overall price movements, such as whether metals exhibit a downward or upward trend during a turbulent period. Silver's mean value is 0.00032, and platinum's value is 0.0002 - very close to zero, a common estimation in high-frequency daily data, as daily changes in financial analysis are typically small.

Hence, the median returns for silver and platinum range from 0.0004, respectively, similar to their mean, close to zero. Their proximity to the means indicates that any influence from extreme values exists, and the distributions are relatively symmetric. However, there is no clear clue that prices tend to rise or drop more often throughout the observation period.

Moving to skewness, both metals exhibit negative skewness, -0.40 for silver and -0.25 for platinum, indicating a left-skewed distribution. This indicates that, despite the majority of daily changes being relatively moderate, some negative returns shift the distribution towards the left. Silver's reaction (platinum's also, but to a lesser degree) tends to be sharper during market stress.

The standard deviation reveals information about volatility levels. Even though the mean returns are close to zero, the values of the standard deviation tell a different story. They suggest that the typical day-to-day shifts are around 1.7%, indicating both series are mainly characterized by short-term fluctuations.

In addition, kurtosis values are higher than 3 - 8.30 for silver and 7.19 for platinum. Their distributions are characterized as leptokurtic, meaning that they have fatter tails and higher peaks compared to a normal distribution. Moreover, silver exhibits a more pronounced leptokurtic form, experiencing more frequent or more intense extreme price shifts, suggesting a tendency for silver to react more sharply to volatility spikes. Platinum's distribution shows a slightly wider center and a less sharp peak related to silver.

Lastly, the Shapiro-Wilk test indicated whether a dataset follows a normal (Gaussian) distribution. In the present study, we examine the normality of log-return series. For both silver and platinum, the null hypothesis of normality was rejected (p

< 0.001 and p < 0.001, respectively). The rejected hypothesis confirms the existence of non-Gaussian properties such as asymmetry, leptokurtosis, and heavy tails, and highlights the necessity for an appropriate econometric model that captures these characteristics.

The following figure shows the aforementioned empirical distribution of daily-log returns for silver and platinum futures:

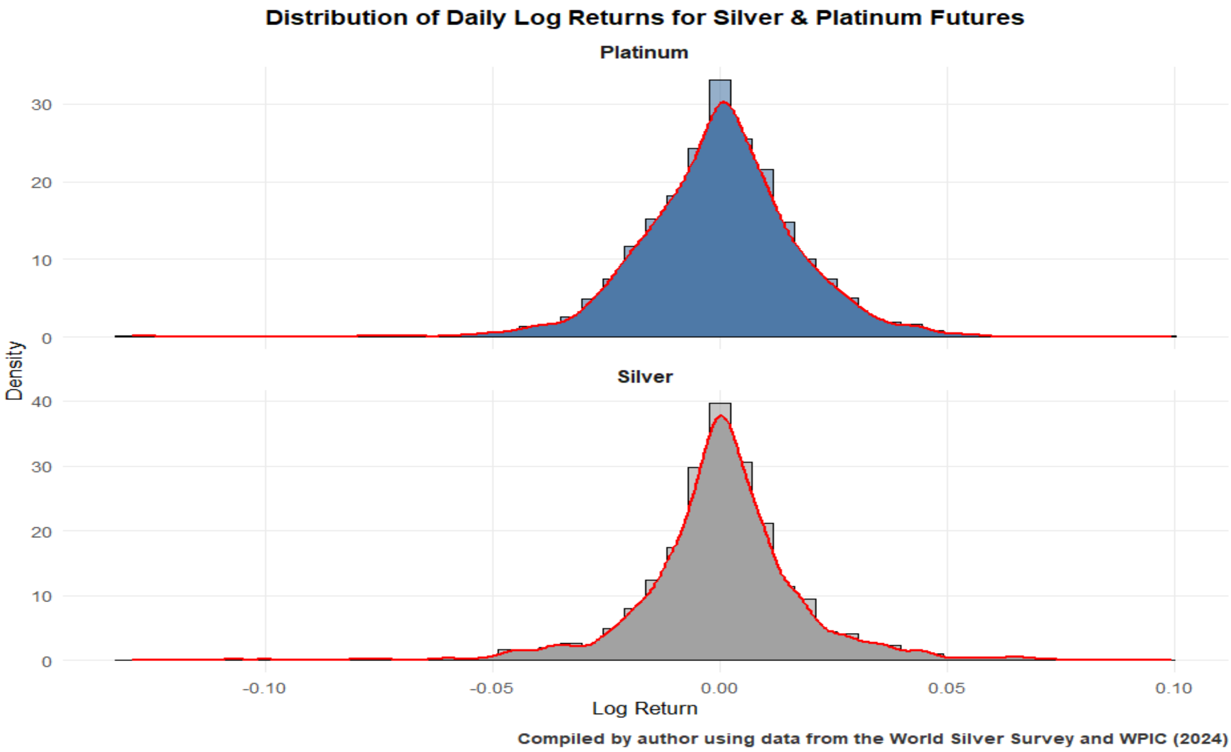


Figure 5: Both distributions display leptokurtic behavior with heavier tails, suggesting probabilities of outliers.

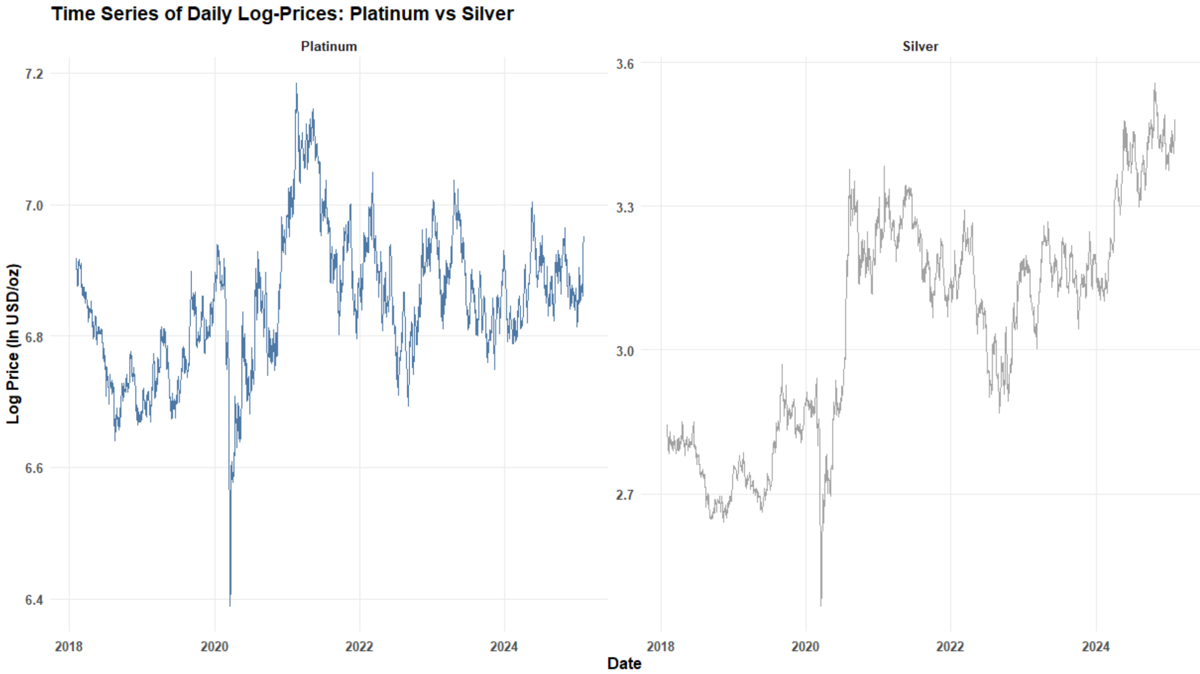


Figure 6: Post-COVID period: Platinum exhibits more intense volatility; Silver follows a stable upward trend.

Compiled by author.

Figure 6 illustrates the daily log prices of silver and platinum futures during 2018-2025. A logarithmic scale is used. The log-prices provide a clearer view of relative percentage change over time, and offer a perspective on prices and trends that both metals follow over time.

The left panel depicts the log prices of platinum. Before the pandemic, values ranged from 6.6 to 6.9, reflecting an unstable pattern. However, during 2020, a sharp decline was observed due to shutdowns and reduced demand for platinum. In particular, the demand in the automotive sector reduced while its investment role started to be more active. Consequently, log prices reached their lowest value over the sample period. Afterwards, the highest level (approximately 7.2) is noted in 2022, owing to the increasing industrial demand and constrained supply. The efforts for green transition raise the industrial demand due to the fact that hydrogen fuel strongly related to platinum (hydrogen fuel uses platinum as a catalyst). It is important to observe that in the post-pandemic phase, platinum's log prices do not follow a stable pattern. Strong fluctuations are exhibited, showing that the platinum market can not balance its behavior in the recovery phase. On one hand, investment demand for silver is less appealing, keeping the prices of platinum at low levels, while on the other hand, supply limitations and the demand for platinum as a replacement for palladium tend to raise the prices, resulting in this instability.

Correspondingly, the right panel shows the log prices for silver. In this case, a different pattern is exhibited. Before 2020, silver prices remain at low levels as not only investors but also the industry sector has shown a moderate interest in silver. The supply successfully absorbs the demand of both sides; as a result, the prices are valued below 3.0. Following this, during the outbreak, the decline in silver prices was also anticipated, due to its strong financial character. During the downturns, most investors liquidated their silver holdings to avoid risk (the heightened uncertainty for precious metals especially in the industrial sector, can reduce prices even more). Nevertheless, between 2021 and 2022, there were again intense fluctuations, as the silver market was trying to deal with the increasing demand. As discussed earlier, in 2022, the investment demand in silver holdings reached its peak, and that is confirmed also here. A decline in price levels explains a second wave of silver sell holdings but this time to a lower degree, as the industrial demand was more balanced compared to 2020. Thus, during 2023-2025, silver prices present an upward trend, owing to the continuous demand from both sides, especially from the industrial field (due to green energy transition, photovoltaics, etc.). These two dynamics rise faster than the supply levels, which in turn drives prices upward.

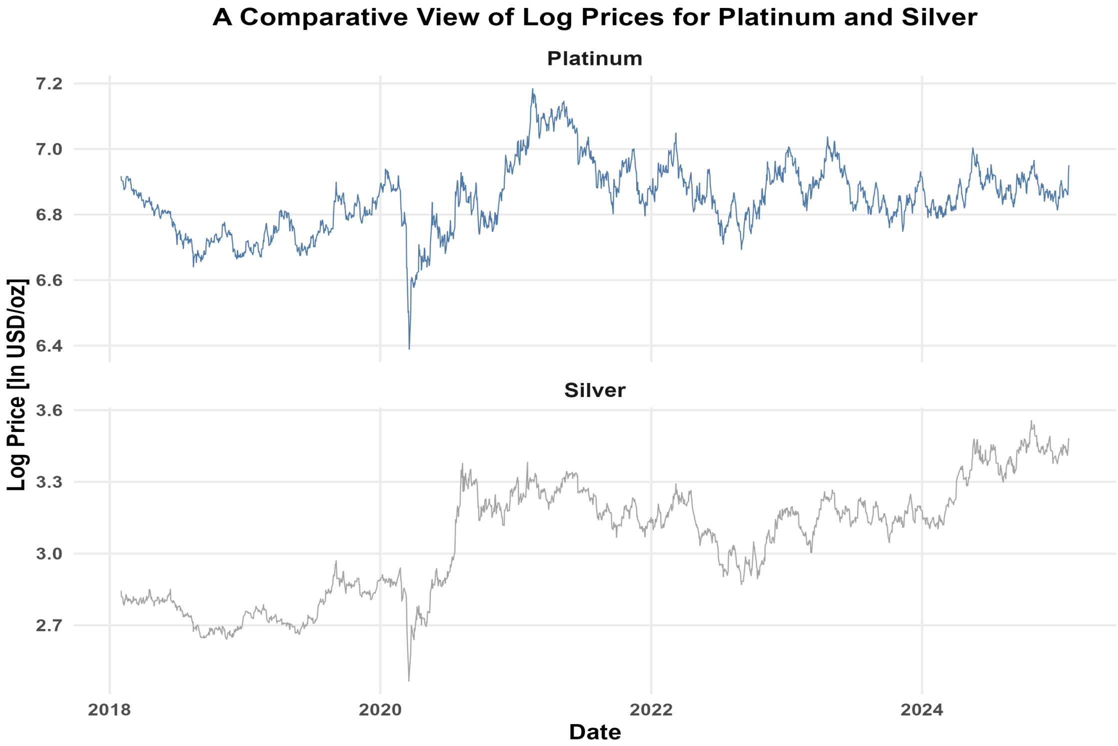


Figure 7: Daily log-prices illustrate platinum's greater volatility, while silver follows a more stable upward trend.

Compiled by author.

Figure 7 illustrates a comparative view of log prices for both metals. As shown earlier, both time series indicate a similar co-movement before the pandemic, with differences in price levels (since platinum prices are higher than silver ones). In raw prices, the highest of platinum was 1,280 USD/oz, while the lowest of platinum was 620 USD/oz. On the other hand, silver's highest value was reached at 35 USD/oz and its lowest at 11 USD/oz. The comparative view helps to better view the concurrent co-movement. The two points that should be considered are i) the sharp and deep decline in 2020 due to the pandemic, and ii) the different patterns that each metals follow in the recovery phase, reflecting the different driving demand factors.

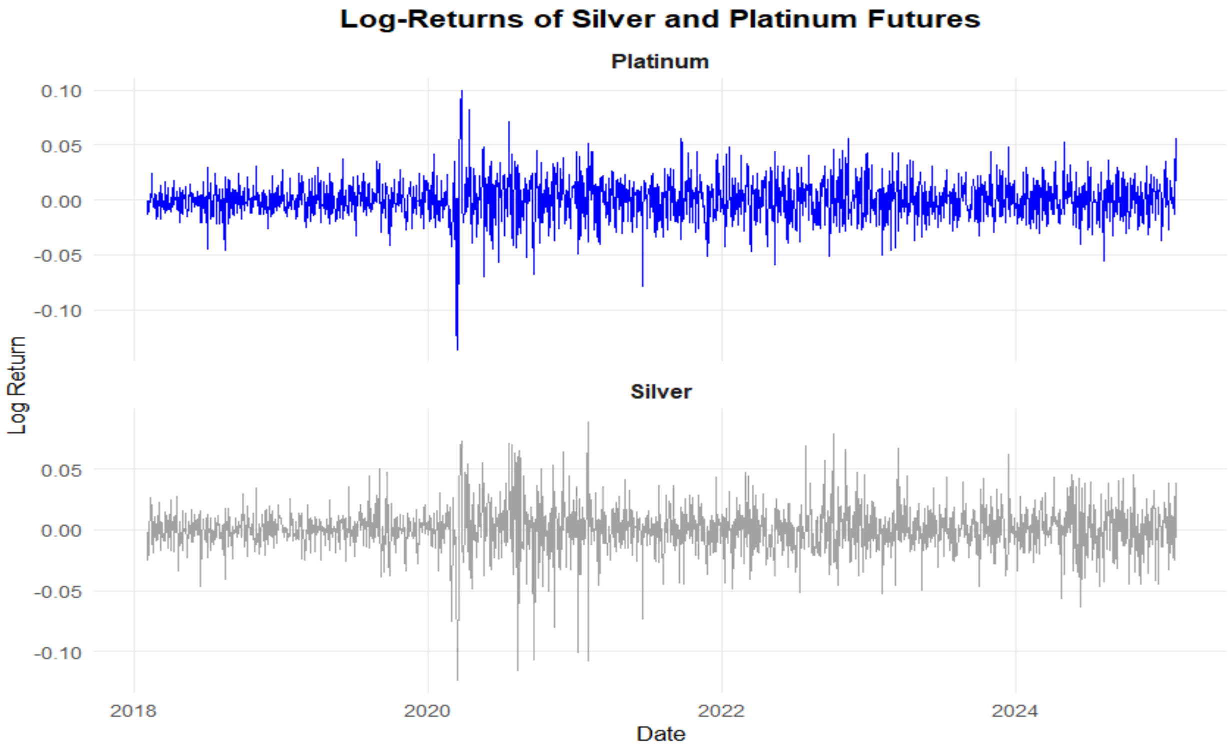


Figure 8: Log-returns of silver and platinum futures exhibit volatility clustering with intense spikes during the pandemic.

Compiled by author.

Figure 8 shows the daily logarithmic returns of platinum and silver. The most common characteristic observed in financial time series is that the mean of returns tends to be close to zero. Prior to the pandemic, returns shows a moderate volatility level, with small fluctuations around the mean. However, during the pandemic, both metals presented a sharp and intense change in volatility levels. In particular, platinum reactions reveal larger price swings compared to silver. Despite both metals suffering in this period due to shutdowns, silver's reactions are more short-lived, abrupt and direct, while platinum's movements characterized by long-term duration responses. Once returns are examined, silver is expected to be more advantageous as its role as a safe investment asset in this period begin to be highly active. After 2021, volatility in both markets decompressed. Silver tend to appear some intense spikes after 2022, possibly due to the Ukraine-Russia war, while platinum seems to hold a more stable pattern. This suggests that silver is more vulnerable to geopolitical and economic shocks - its dual nature exposes it to a wider range of risks.

Table 2: Correlation between Silver and Platinum log-returns

Method	**Correlation**	**p-value**
Pearson	0.581	< 0.0001
Kendall	0.396	< 0.0001
Spearman	0.557	< 0.0001

This study applies Pearson's correlation coefficient and Kendall's tau rank correlation to evaluate the level of co-movement among silver and platinum. The methods are selected to offer a comprehensive explanation of the linkage between the metals. The Pearson coefficient indicates the linear association between two variables, considering normality and sensitivity to outliers. The Kendall's tau is a non-parametric measure that uses the order of the data, helping not to be affected by outliers and capture non-linear relationships, which we often meet in financial data.

As shown in **Table 2,** the Pearson correlation is **0.581**, explaining a moderate to strong linear relationship. The returns of silver and platinum tend to move in the same direction, affected by common economic and financial effects. The Kendall's tau coefficient points a **0.396** degree of correlation, meaning a statistically significant monotonic association between the two time series. More precisely, as the return of one metal increases or decreases, the return of the other metal will also follow the same pattern.

The difference between Pearson's and Kendall's in values coefficients is expected due to their rank-based formulation, which is less influenced by extreme values or non-linear relationships. Therefore, both coefficients are highly statistically significant (p-value < 0.0001), supporting that the co-movement is not a result of a random walk. The current findings suggest a connected link between silver and platinum returns, supporting further analysis of their dynamic linkage. Pearson correlation at 0.557 confirms that the strength and direction among the metals is moderate to strong.

Figure 9 depicts the scatter plot of the relationship between the log-return of silver and platinum, with marginal histograms explaining their distribution.

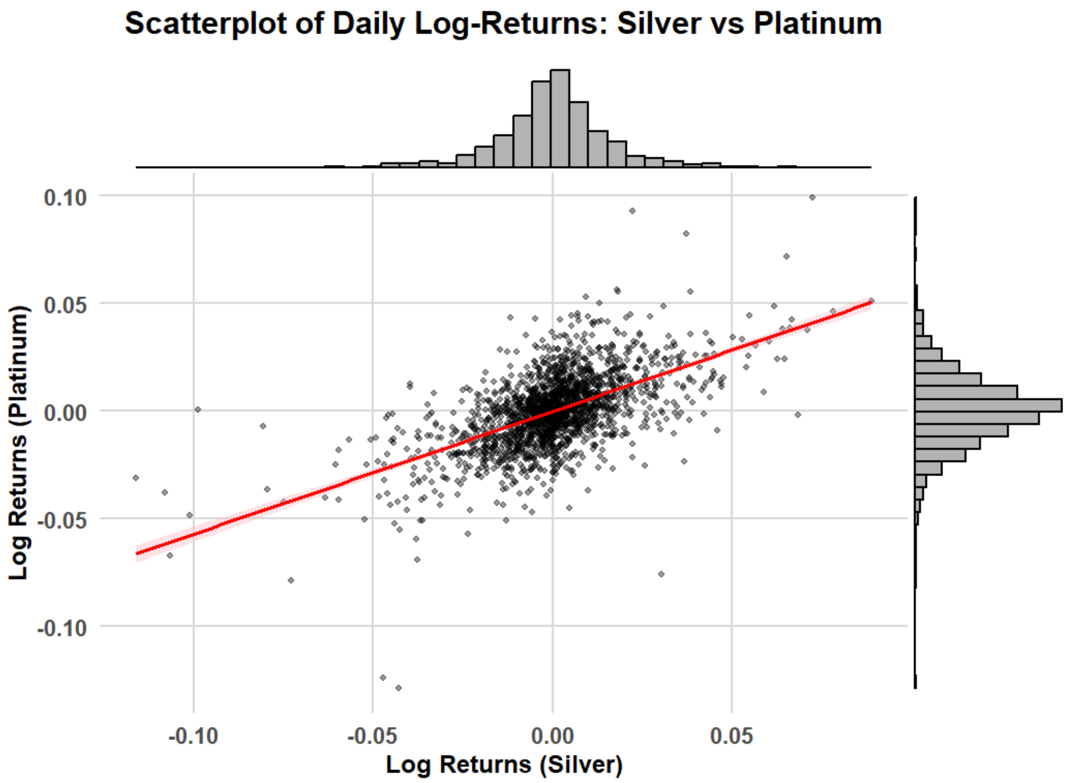


Figure 9: Log-returns of silver and platinum futures illustrate stronger correlation in the mid-range, while the greater spread observed around outliers.
Compiled by author.

The scatter plot illustrates the daily log-returns of silver and platinum, whereas each point represents a daily pair of return prices for the period 2018-2025. The fitted regression line describes the best linear approximation of their relationship, while the shaded area shows the 95% confidence interval. The marginal histograms in the top and right panels show the distributions of each metal. Both distributions point sharp peaks and heavy tails, confirming the leptokurtic characteristics discussed earlier. Therefore, the mild left skew suggests that extreme negative returns appear more often than positive ones.

The plot reveals a clear positive association between silver and platinum, showing that when the return of silver increases, platinum tends to follow - and vice versa. In the middle-range area (i.e., observing log returns of -0.015 and 0.015), the dots are tightly clustered along the regression line. Under normal market conditions, silver and platinum exhibit a strong and stable co-movement, with most daily prices changing in the same direction and with a similar ratio.

The dots that are far from the regression line indicate uncertainty periods. At the lower extreme, specifically when silver returns reached below -0.05 (-5%), the spread of platinum returns becomes wider. Several pairs follow a similar decreasing movement while others diverge importantly, highlighting the weaker co-movement during crisis periods. In general, when silver tends to decrease, platinum does not present the same magnitude in decline. For example when silver returns diminished at %10, platinum reacts with losses close to %5. On the other hand, at the upper end of the distribution, when silver returns exceed 5% , the dispersion remains wide (though not as wide as at the lower) but more steady. This indicates that the co-movement of the two metals is stronger in positive price shifts than during negative ones.

In order to apply the Wavelet Local Multiple Correlation (WLMC) methodology, stationarity must be tested. Table 3 presents the Augmented Dickey-Fuller and Phillips-Perron tests. Both series are converted to log-returns. The log-prices of platinum are stationary. On the other hand, the log-prices of silver are not stationary. The first differences of both time series are stationary.

Table 3: Augmented Dickey–Fuller (ADF) Unit Root Test

	With a Constant only	**With a Constant & Trend**	**Lag(s)**
Levels			
Silver	-1.96	-2.43	1
Platinum	-3.42**	-3.42**	1
First Differences			
ΔSilver	-25.15***	-25.14***	1
ΔPlatinum	-36.14***	-36.22***	1

Notes: Δ denotes first differences. ***, **, * indicate rejection of the null hypothesis of a unit root at the 1% (-3,43), 5% (-2,86), and 10% (-2,56) significance levels, respectively.
Results were produced using *EViews* software.

Table 4: Phillips–Perron (PP) Unit Root Test

	With a Constant only	**With a Constant & Trend**
Levels		
Silver	-2.05	-2.54
Platinum	-3.24**	-3.24**
First Differences		
ΔSilver	-25.15***	-25.14***
ΔPlatinum	-36.61***	-36.60***

Notes: Δ denotes first differences. ***, **, * indicate rejection of the null hypothesis of a unit root at the 1% (-3,43), 5% (-2,86), and 10% (-2,56) significance levels, respectively.
PP statistics were based on Newey-West corrections.
Results were produced using *EViews* software.

4 Methodology

4.1 Analytical Framework

In this section, we present the mathematical framework in which the empirical approach is based. The analysis examines the time-varying linkage between the platinum and silver futures markets across multiple horizons. First, we transform raw price data into returns, which allows us to proceed to a multiscale correlation investigation using wavelet methods. To ensure uniform daily frequency required for the WLMC estimation, we used linear interpolation in R to handle the missing observations due to weekends and holidays. This pre-processing procedure helped both the platinum and silver series to be aligned, avoiding distortions from irregular spacing.

Formally, let Pt denote the closing price of the asset (platinum or silver) at the time t. The continuously compounded return (logarithmic return) is computed as:

$$r_t = \ln(P_t) - \ln(P_{t-1}) = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

where r_t denotes the return at time t (Tsay, 2005).

To compute the volatility correlation, we used the realized volatility, which is defined as the squared logarithmic returns (see Equation (2) Andersen and Bollerslev (1998). This measure captures the magnitude of daily price fluctuations and is commonly used in financial approaches and volatility forecasting.

$$v_t = r_t^2 \tag{2}$$

The correlation between the two assets changes in two dimensions, over time, and in different frequencies (i.e., timescales). Percival and Mofjeld (1997) distinguishes the DWT from MODWT, as in wavelet multiresolution analysis, a time series can be explained in the detail components Dj(t) side, which reveal information about short-term movements, and the smooth component Sj (t), capturing long-term movements.

$$x(t) = \sum_{j=1}^{J} D_j(t) + S_J(t) \tag{3}$$

where:

•$D_j(t)$ is the detail components at the scale j, indicating fluctuations in the 2^j period range (e.g.,2-4,4-8 days etc.).

For example:

$$\text{Scale } j \;\Rightarrow\; \text{period range } [2^j,\; 2^{j+1}) \text{ days} \tag{4}$$

•$S_J(t)$ is the smooth component indicating long-term trend beyond the largest scale.

This decomposition is also referred to in the literature from Gençay et al. (2002) and Sjölander et al. (2015).

The variance of the original series can be computed as the sum of the variances of its wavelet components:

$$\text{Var}(x(t)) = \sum_{j=1}^{J} \text{Var}(D_j(t)) + \text{Var}(S_J(t)).$$

This multiscale decomposition explains the variability across short, medium, and long-term horizons (Percival and Walden, 2000), Percival and Mofjeld (1997).

Finally, to capture the degree of correlation between the decomposed series, the Wavelet Local Multiple Correlation (WLMC) method was introduced by Fernández-Macho (2012). WLMC is a multivariate extension of wavelet correlation that assesses the strength of the correlation in time series across time and scale. In the bi-variate case, where only two series are involved, the WLMC at time t and scale j simplifies to a particular scale-level, rolling correlation:

$$\text{WLMC}_j(t) = \frac{\text{Cov}(X_j(t), Y_j(t))}{\sqrt{\text{Var}(X_j(t)) \cdot \text{Var}(Y_j(t))}} \tag{5}$$

where

$X_j(t)$ and $Y_j(t)$ are the wavelet coefficients of the platinum and silver series, respectively, at scale j and t time t. This shaping enables the correlation to vary locally simultaneously in time and frequency scales, including structural swings that might be disguised in traditional correlation analysis.

In addition, the WLMC results have been visualized with heatmaps, which reveal the dominant correlation direction, meaning which asset leads the correlation. This approach emphasizes intervals in which the linkage is asymmetric due to exogenous shocks. The application is based on the VisualDom package in R, using appropriate decomposition tools Polanco-Martínez (2023). Finally, to evaluate the statistical significance of the estimated correlations, the confidence intervals are computed for each scale. This reveals whether correlation patterns are reliable and statistically significant, or whether they rely on random noise.

$$\mathrm{CI}_\alpha \left[\mathrm{WLMC}_j(t)\right], \tag{6}$$

where α denotes the chosen significance level (e.g., $\alpha = 0.05$).

4.2 Empirical Results

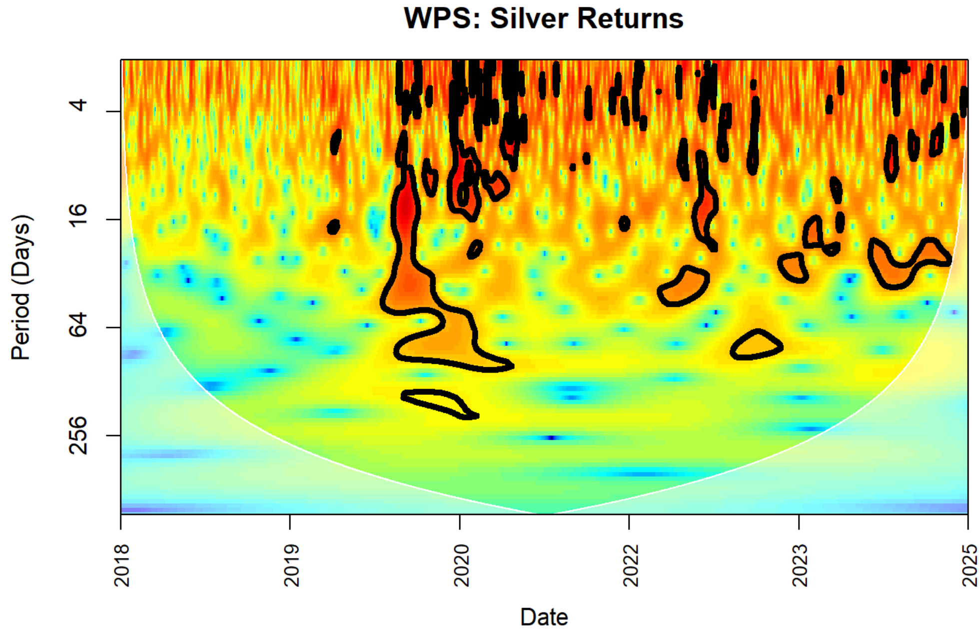
4.2.1 Wavelet Variance for Individual Series

The analysis was conducted based on logarithmic returns and the realized volatility (squared returns) of the time series. The empirical results were produced using R statistical software. Correlation plots and dominance heatmaps for each timescale are used to illustrate the findings.

The sample was divided into eight time scales: i) very short-term interval (2-4],[4-8] days, ii) short-term (8-16] and medium-term [16-32) area, iii) medium-to-long-term period (64-128], iv) long-term area (128-256) days, plus a final Smooth component. This decomposition helps distinguish whether correlations between the two metals are persistent or temporary and scale-dependent.

Firstly, the wavelet power spectrum is used to illustrate the way variance is distributed in different time-frequency scales. The WPS allows us to detect the intensity and the magnitude of variance per time scale. As follows, warmer colors indicate higher power, meaning stronger fluctuations, while cooler colors explain weaker variance (more stable phases). In both figures, the black lines represent areas where variance is statistically significant at the 5% level. These outlines explain that the variance pattern within these areas is less likely to come from random noise, adding more confidence to the results.

4.2.2 Wavelet Coherence Between Silver and Platinum



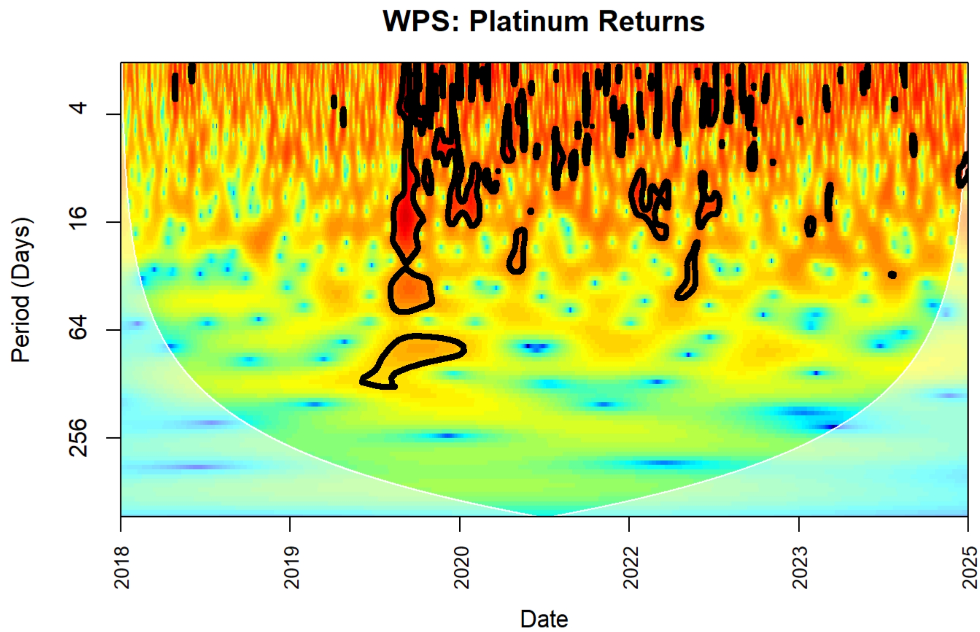


Figure 10: Time - Frequency Variance of Silver and Platinum Returns. *Compiled by author.*

The upper figure shows the silver power spectrum. In 2020 and at all frequencies, the variance appears to be more extended due to the pandemic. From 16 to 256 days, the variance is more persistent. The continuous, intense variance indicates that during the pandemic, silver has no stable behavior in its returns. To be more detailed, in the first quarter of 2020, returns of silver have quickly decreased, while the next quarter functioned as a safe haven asset, resulting in increases in returns. However, in 2021, the variance is more concentrated in high frequencies (4-16 days) and more temporary. Despite this, during 2022-2025, no continuous variance at any timescale is observed, except for medium-term periods (32-64) days. Partial episodes of intense variance are presented. Silver holds more of a financial character; as a result, movements are more apparent in medium terms (investors rely on medium-term expectations rather than short-term industrial dynamics).

The bottom figure depicts the power spectrum for platinum. In 2020, the variance was also intense at most frequencies, and less in the 128-256 day scale. The pandemic has also affected the platinum market in a similar way to silver. Shutdowns and reduced demand cause fluctuations in returns; however, not as intensely as in the silver ones. The industrial character of platinum and the limited supply cause more frequent episodes of variance. After the pandemic, phases of instability are observed mostly in high frequencies, while in medium- and long-term horizons, no major variation episodes appear. The post-pandemic phase reveals smoother changes in the platinum market. The stabilization in demand levels and the initial recovery of industrial production reduced the price fluctuations.

Comparing the two metals' variance returns, both silver and platinum tend to show greater and persistent variance during the pandemic, while in the recovery phase, each one follows a different pattern. Platinum keeps more concentrated episodes of instability in higher frequencies; on the other hand, silver exhibits more dispersed variance bursts.

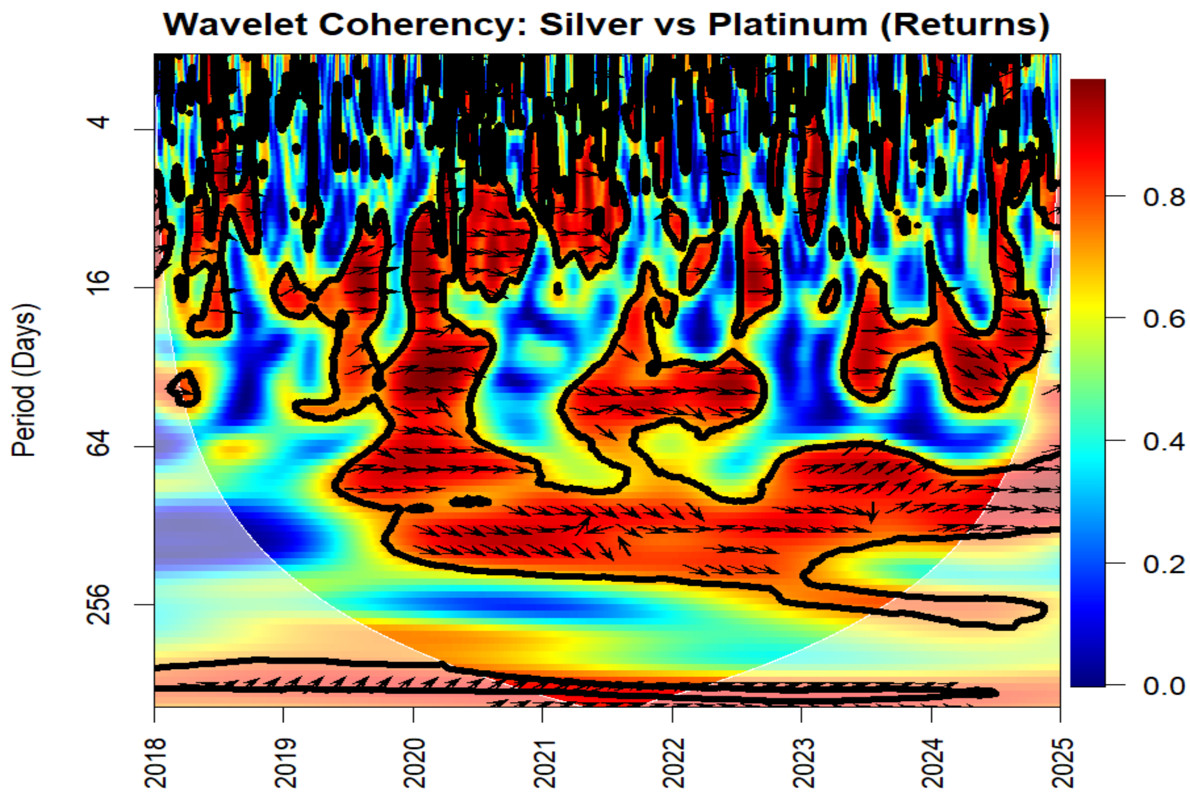


Figure 11: Wavelet Coherency Correlation - Silver vs Platinum.
Compiled by author

The wavelet coherency plot shows the linkage between silver and platinum futures over time and across different time scales. The vertical axis represents the scale in days, while the horizontal axis shows years. The color intensity indicates the strength of correlation at each point in time and frequency.

•Red and dark orange areas indicate strong positive co-movement

•Blue zones suggest weaker or no correlation.

•Arrows pointing right direction suggest that both markets move in alignment (positive correlation)

•Arrows pointing left side, explain opposite movement (negative correlation)

•Arrows pointing up and down suggest that one series leads or lags the other. Figure 11 illustrates further the dominance between two variables over time.

The contours around red regions indicate zones of statistically significant coherence.

In short-term periods (2-16 days), coherence is more fragmented and recurring. Scattered red patches exist but are not persistent, explaining that the coherence between silver and platinum is more sporadic and short-lived.

In the medium-term area (16-64 days), coherence becomes more intense, revealing stronger and more sustained relationships, specifically around major events. For instance, when the pandemic outbreak began, coherence tended to increase significantly in this range.

In the long-term range (64-256 days and beyond), a more consistent and pronounced coherence pattern is observed. The red regions with right-pointing arrows show that silver and platinum tend to have the strongest coherence over all time-scales, possibly due to mutual economic fundamentals such as inflation or industrial demand. The consistent right-pointing arrow suggests a positive and stable environment with no strong leader-follower pattern.

[6]

4.2.3 The WLMC results for silver and platinum returns

Figure 12 shows the correlation of returns for each time-scale and for the sample period. The green line represents the estimated correlation level and the red spots the confidence intervals.

[6] The Cone of Influence (COI) includes more reliable results. Areas outside the cone, specifically near the edges, may provide less accurate explanations due to boundary effects.

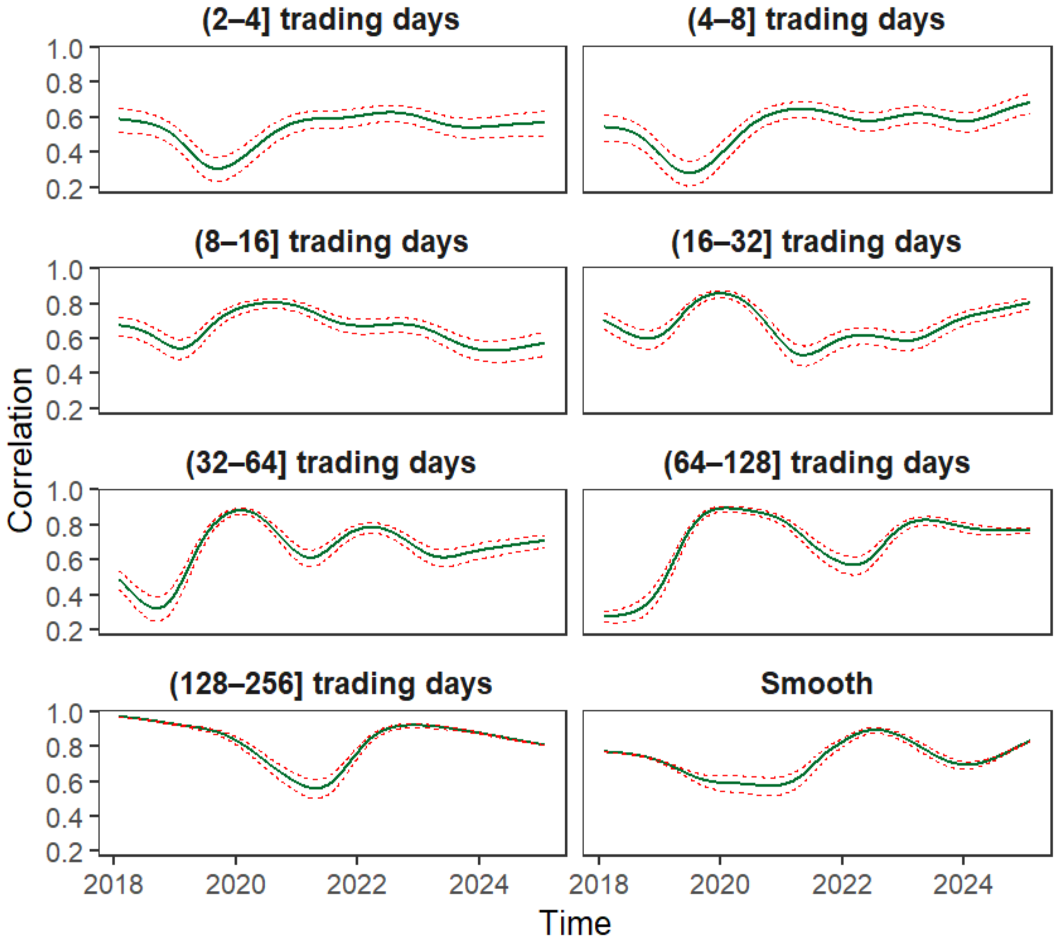


Figure 12: WLM correlations between platinum and silver returns across multiple timescales.

In the very short-term period (2-4] and (4-8] days, the correlation of returns is moderate but positive and statistically significant, with values mostly ranging from 0.2 to 0.6. In 2020, the decline in correlation was due to the pandemic. At high frequencies, each metal reacts differently to exogenous shocks and at a different rate. During the pandemic, silver's reactions were quick but more abrupt. Investors tried to reduce their exposure to risky assets, resulting in heavy "long liquidations" of silver in mid-March Focus (2021). On the other hand, World Platinum Investment Council (2020) underlines that platinum reactions to the pandemic started earlier, particularly in late January. Initial lockdowns in China caused reduced demand. Since the impact of the pandemic started earlier, the decline in mid-March due to the general outbreak is characterized as more gradual compared to the silver. This difference in reaction to initial shock causes the short-lived decoupling between silver and platinum. In the following years in this interval, a higher level of correlation is shown, but still unstable. The various short-term factors for silver and platinum make their relationship more fragile during market stress.

In the short-term horizon, 8-16 days, the correlation became stronger. The influence of the very short-term factors is gradually disappearing. The most important change in this timescale was observed in 2020, where the correlation is strengthened, reaching almost 0.8. During the outbreak of the pandemic, both metals' returns were reduced. These findings are in line with Bentes (2022), who noted that silver and platinum returns present a sharp decline around mid-March 2020. Silver exhibits moderate positive asymmetry before and after the pandemic, while platinum presents negative asymmetry before and positive after. Later this year, silver and platinum returns increased, silver's rebound being stronger owing to its attractiveness as a safe haven asset.

In the medium-term horizons (16-32] and (32-64] days scale, a cyclical pattern is observed. The two metal markets are affected by common economic cycles. Since platinum holds a strong industrial role, it tends to follow economic cycles more closely. At the same time, silver is also affected by these cycles, but to a lesser degree, as the main influence comes from the investment use. Huang and Kilic (2019) analyzed the gold-platinum ratio and indicates that platinum prices are highly affected by industrial activity as a procyclical metal, resulting in sharp reactions during recession (compared to gold). Silver's reaction during a crisis tends to be even more sharp due to its safe-haven role Bentes (2022). This leads to a more stable and stronger positive (and statistically significant) correlation during turbulence periods. In particular, in 2020 a higher level of correlation was observed between silver and platinum returns. These findings are consistent with Yıldırım et al. (2022), who shows in the analysis (which examines oil and precious metals) that platinum is characterized as a metal strongly related to industrial cycles, and during the pandemic, the co-movement between precious metals - including silver and platinum - changed. The negative correlation between oil and silver became weaker, while platinum is synchronized with oil. The two metals tend to react more similarly. However, in 2021, the correlation softened due to different market conditions in each metal. The demand for silver was extremely high due to photovoltaics, while platinum held a more stable demand level The Silver Institute and Metals Focus (2022) Council (2022). Between 2023 and 2025, the correlation follows an upward trend.

In addition, in the medium-to-long-term period, including the (64-128] days scale, the cyclical pattern became smoother (and statistically significant), with strong correlation values in 2020 again. In contrast with the short- and medium-term intervals, the correlation here was weaker during 2018-2019 and again in late 2021. The findings of Kucher and McCoskey (2017) are also consistent with the estimated correlation in this interval, which supports that long-term relationships among precious metals (including silver and platinum) vary under different macroeconomic conditions and are characterized by instability. They show that the cointegration relationship tends to be stronger in recessions and weaker during expansions. Banerjee and Pradhan (2021) shows that between precious metals and equity indices, the correlation becomes stronger after the pandemic. Nekhili et al. (2021) noted that during the pandemic, the co-movements between precious metals became stronger.

Finally, the long-term scales, namely (128-256] days scale, exhibit the highest level of correlation (and statistically significant) between silver and platinum across all frequencies and over the sample period. In this timescale, each metal shared common macroeconomic drivers, resulting in higher correlation levels. Dinh et al. (2022) is in line with this, showing that macroeconomic fundamentals, such as interest rates and inflation, affect the links between precious metals. The higher the interest rate, the weaker the correlation becomes. The steep decline in 2022 is related to the increasing ratio of interest rates. In particular, in March 2022, the Fed applied tightened monetary policies, resulting in the most rapid rise of interest rates since 1980 Arteta et al. (2022). The higher interest rates affect the silver market more. The investment demand decreased due to lower expected returns in silver, while the platinum market was affected less.

Tweneboah (2019) is in line with this pattern; their analysis focused on six industrial metals and found that the correlation is scale-dependent, with stronger values appearing at longer investment horizons, which leads to a more stable relationship in lower frequencies. The authors highlight that the short-term shifts in prices appeal more traders and speculators, whereas long-run co-movements are important for hedgers and arbitrageurs. Nekhili et al. (2021) agreed with the co-movement pattern. They found that among other metals, silver and platinum present a strong dependence behavior and their correlation tends to strengthen in medium- and long-term periods. The Smooth component describes the long-term tendency of the correlation of returns. The pattern on this scale reflects the average long-run evolution of their relationship. Before 2020, the correlation was moderate-to-strong as observed at the most scale. From 2021 onwards, the correlation peaked, which explains the strong level observed in low frequencies.

Figure 13 displays an alternative approach for correlation of returns. The intensity and the persistence of the correlation of returns are identified by the color coding. For example, lighter colors (yellow/orange) indicate weak to moderate correlation ranging from 0.00 to 0.50, while warmer colors (dark purple) illustrate strong correlation levels close to 1.00.

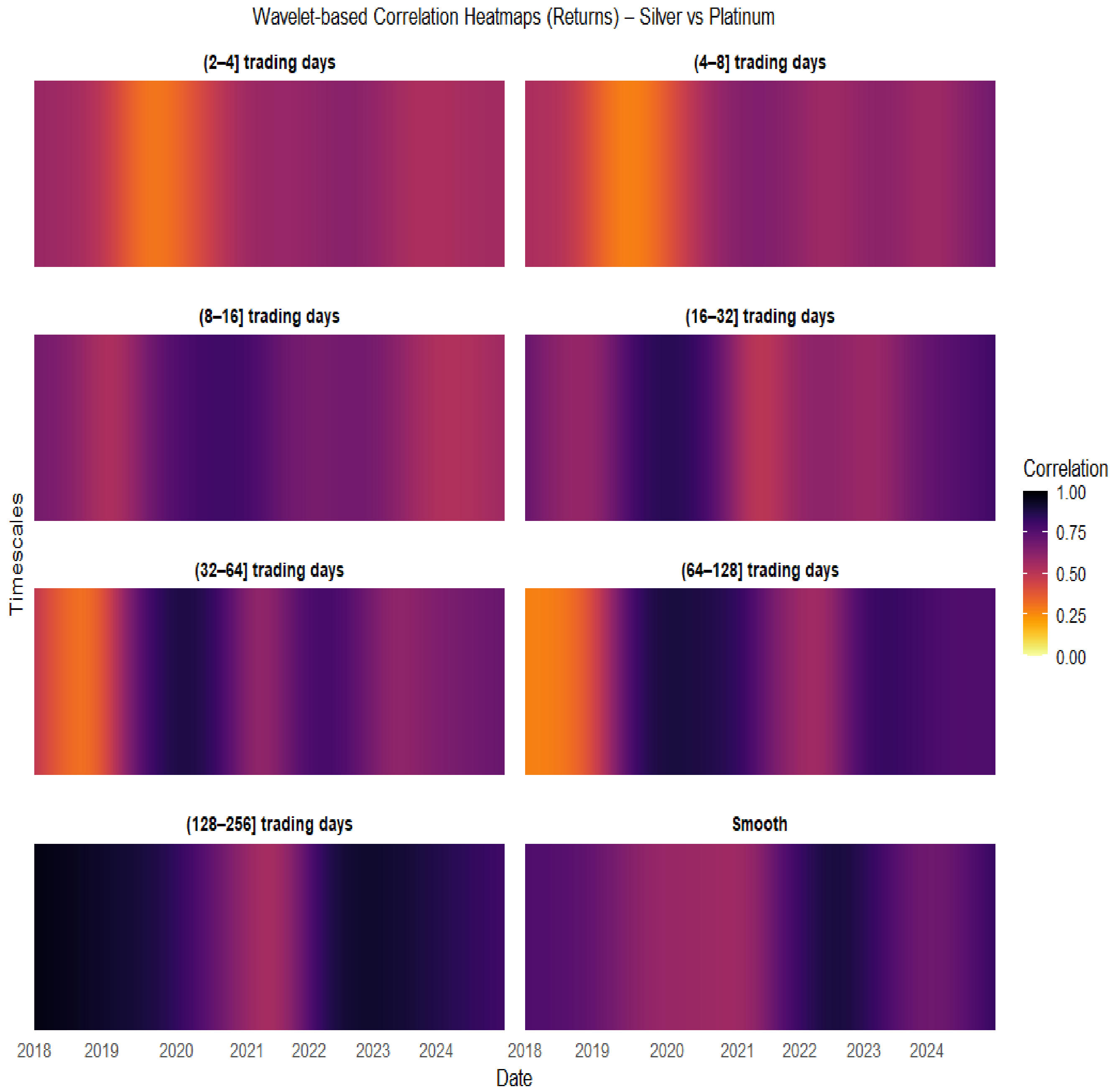


Figure 13: Wavelet-based correlation heatmaps between silver and platinum returns

Similarly, at higher frequencies, colors are milder, indicating a moderate relationship as well. In the medium scales, the linkages among the two metals are stronger. Thus, it is clear that between the medium-to-long and the long-term frequencies, their interaction becomes more stable due to common economic cycles, with the latter interval underscoring the highest level in correlation. Values reached almost

1, and the purple color confirms the strengthening relationship. The visualization of wavelet heatmaps shows us that the correlation between the two metals is not stable, since the multiscale varies over time. While in the short-term linkages are lower and fragile to sudden shocks, in the medium- and long-term frequencies are almost perfectly synchronized (dark purple), emphasizing the significance of their dual role.

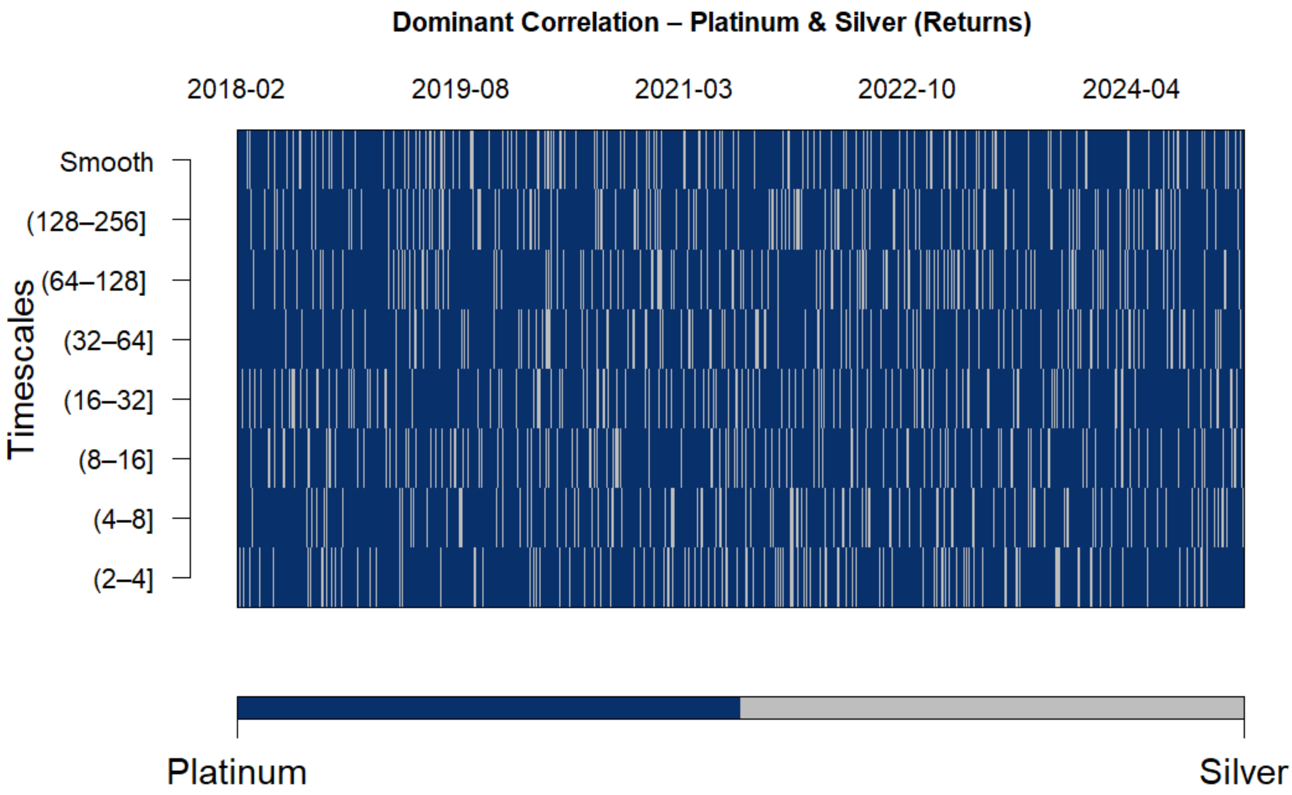


Figure 14: The dominant heatmap of returns

Since the previous figures illustrate the level of correlation, Figure 14 is presented to complement the WLMC analysis of returns. Each row corresponds to a specific frequency level. The horizontal axis represents the sample period, and the vertical axis the time scales defined earlier. Therefore, blue and gray patches represent platinum and silver, respectively. In the context of WLMC, the dominance heatmap identifies the variable that exhibits the highest local multiple correlation Fernández-Macho (2018). Platinum dominates across the majority of timescales. However, Polanco-Martínez (2023) noted that WLMC dominance could be related to phase differences. The dominant variable tends to follow the changes of others. The clear phase information about derives from wavelet coherence figures (see Figure

11). Consistent with this asymmetry, (Batten et al., 2015) found that volatility shocks are transmitted from silver to platinum. Silver tends to respond earlier than platinum to shocks, but exhibits idiosyncratic price movements that are not fully transmitted to platinum. By contrast, platinum adjusts to silver's movements and reacts whenever silver changes. Platinum is identified as the dominant asset since its price dynamics capture the joint relationship more effectively than silver on its own. Although gray patches are frequent after 2020, reflecting that silver maximizes the local multiple correlation and holds a partial dominant role (heightened investment and industrial demand observed in recent years) (Institute, 2025; Metals Focus, 2024).

4.2.4 The WLMC results for silver and platinum realized volatility

Figure 15 shows the dynamic correlation of the squared returns (realized volatility) for both metals. The same time scales, from (2-4 days) to (128-256 days) are similarly used for this analysis. The correlation of volatility shows whether silver and platinum experience similar fluctuations. A higher correlation implies that both metals become more volatile or stable simultaneously, while a lower degree indicates unsynchronized movements or with different intensity.

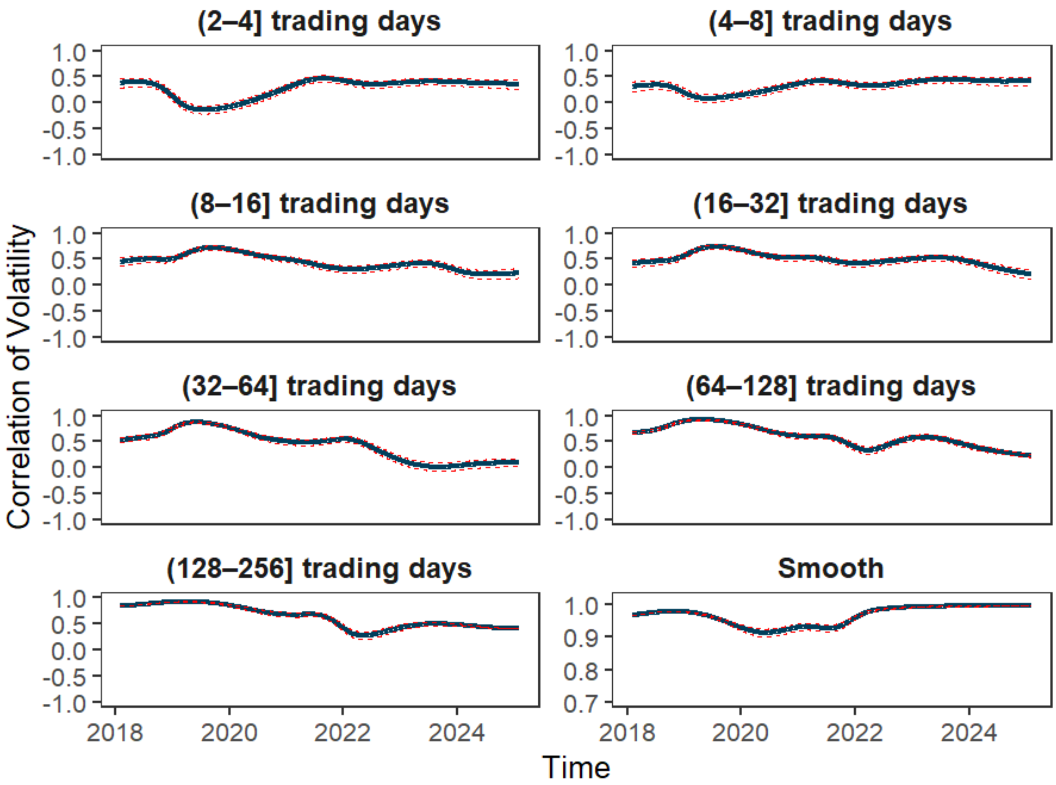


Figure 15: WLM correlations of realized volatility between platinum and silver

In high frequencies (2-8] days, the correlation of volatility is moderate, positive, and statistically significant. Similarly to returns, during 2020, the correlation is weakened. This does not imply that one metal reacts and the other does not, but as presented earlier, platinum movements tend to be slower and less volatile in the very short term during the pandemic. Despite both metals reacting to COVID-19, their responses have different ratios.

In the short-to-medium-term interval, namely (8-64] days, the correlation of volatility remains positive and statistically significant, with the only peak in 2020, reaching 0,75. The findings of Bentes (2022) are also consistent, indicating an increased volatility level between precious metals, including silver and platinum, but a less persistent volatility level in the post-pandemic period. Similar findings were presented by Raza et al. (2023), who shows that during global crisis and uncertainty periods, volatility tends to be more persistent (especially in the pandemic), with silver presenting a less secure asset in the pre- and post-pandemic period. The results are in agreement with Gil-Alana and Poza (2024), who found that volatility among precious metals tends to be more persistent during shocks; however, it decreases over time. Their results also show that platinum's volatility is higher compared to silver's, probably due to the latter holding the safe haven character.

In the post-pandemic period, a continuous decline is followed, indicating that the two metals tend to synchronize during a crisis and decouple in the post-pandemic phase. Raza et al. (2023) highlights that high levels of volatility are short-lived during 2020 and decrease after 2020 due to the mean-reverting nature of precious metals.

The mid-to-long-term horizon (32-128] days, the correlation of volatility follows a similar pattern with no major change. It is important to note that the upward trend that appears in correlation during 2022 is due to the Russia-Ukraine war. Both metals present a volatile behavior during the crisis period, but with a lower intensity observed during the COVID-19 pandemic.

Finally, in low frequencies, including the (128-256] days scale, it is shown that in 2018, the two metals had the strongest and almost perfect correlation in volatility over the sample period, reaching values around 1.00, while after 2022, the volatility of each metal separated significantly until 2024, with values reaching below 0.50. The lowest point in the long term is observed in late 2022, and after that, the correlation remains unstable but positive and statistically significant. These results are in line with Batten et al. (2010), who found that monetary factors are not statistically significant for silver's volatility levels. Instead, silver volatility exhibits a stronger speculative character, while platinum volatility is associated more to financial and macroeconomic conditions.

The Smooth Component captures the general long-term trend, which shows a steady and high trend, near 1.00. Financial factors such as inflation expectations and monetary policy cycles similarly affect silver and platinum in the long-term horizons, while the short-term impacts have faded.

Overall, the correlation of volatility between silver and platinum becomes tighter during the COVID-19 pandemic and weaker in the post-pandemic period. In contrast with the correlation of returns, no cyclical pattern is observed. The decline in the recovery phase is continuous, indicating their different dependence on demand factors.

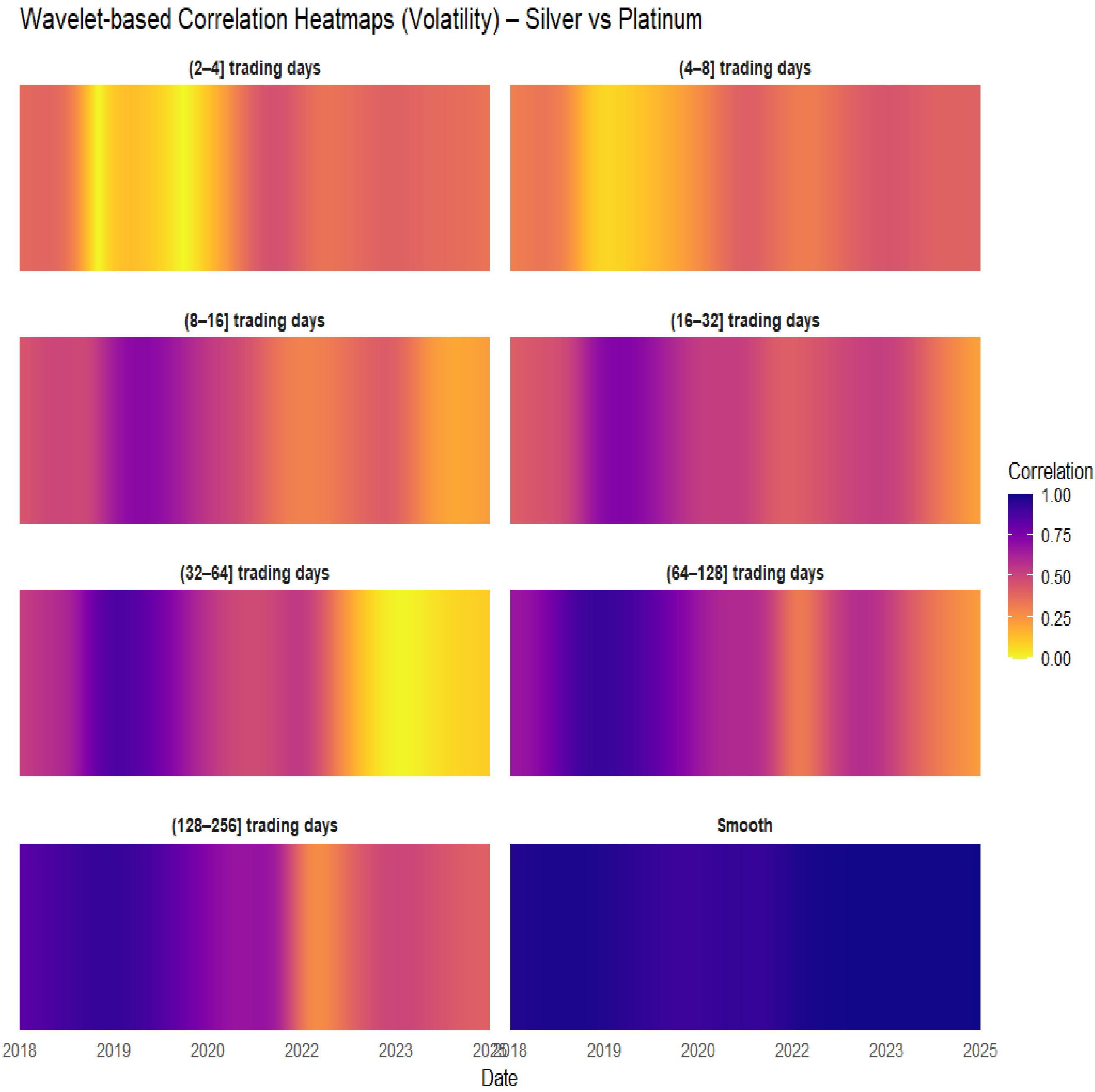


Figure 16: Wavelet-based correlation heatmaps between silver and platinum - Volatility

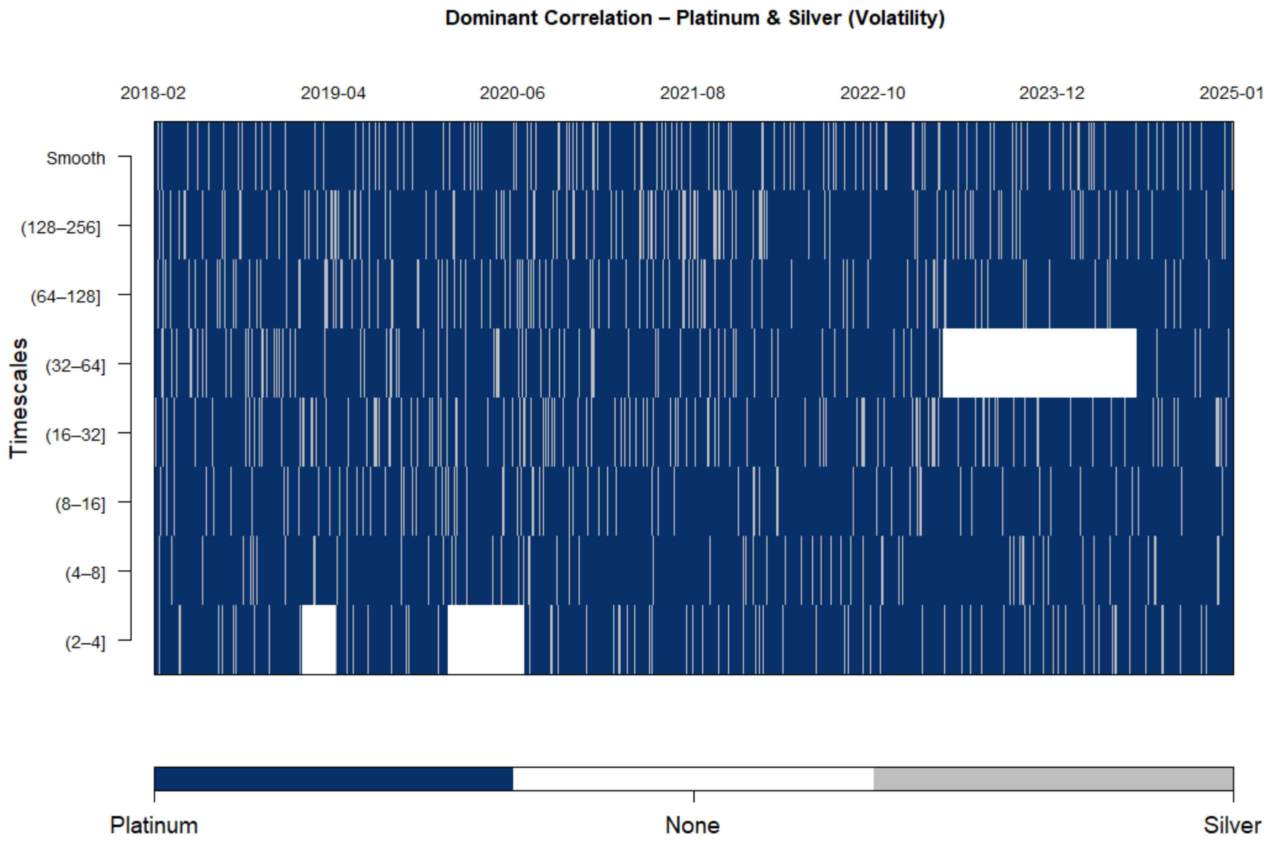


Figure 17: The dominant heatmap of volatility

Following the same analysis of WLMC applied to volatility, the dominant heatmap reveals that platinum acts as the dominant variable across most timescales and over the majority of years. In the context of volatility, dominance shows a higher degree os synchronization with the joint volatility dynamics of the system rather than heightened volatility.

Platinum's dominance is clearly stronger in the very short-term horizons, (2-8 days), especially during 2019-2020 and again during 2023, suggesting a closer adjustment to high-frequency fluctuations. This pattern indicates that volatility shocks are more consistently absorbed and reflected in platinum, rather than implying that platinum generates these shocks. The majority of literature has found that due to its more speculative and volatile character, silver exhibits sharper, faster and more short-lived reactions compared to other precious metals. They often called it "cheap gold". By contrast, such behavior does not imply in the platinum market. This means that platinum volatility reflects more closely the shared volatility behavior of silver and platinum,

In the middle area, platinum continues to exhibit strong dominance during 2021-2022 and again in some periods during 2023-2025. However, silver assumes dominance in the medium-term horizons, but those episodes are short-lived, indicating that silver's volatility captures the joint system dynamics less frequent over extended intervals. Episodes of increased platinum volatility are associated with supply disruptions such as mining production issues due to power cuts (World Platinum Investment Council (2023), World Platinum Investment Council (2025)) in platinum production coincide with periods where platinum reflects the joint volatility dynamics of the system.

The white block in the [2-4] and the [32-64] time-scale suggests no clear dominance, otherwise area where there is no statistical significance. This arises from the correlation of volatility; in these time-scales, the correlation was zero, resulting in a neutralization of their linkage and statistical insignificance. Each metal's volatility moves in a different direction.

In the long-term period, gray patches became more frequent and thicker before the pandemic. Vigne et al. (2017) noted that silver tends to be more stable during low-interest periods and less volatile. However, platinum re-emerges as the dominant volatility asset during 2021-2022. The Smooth component further confirms the dominance of platinum, with silver holding a significant position in most years.

5 Discussion

The results of this study show that silver and platinum hold a dynamic and time-varying correlation, with high volatility during turbulence periods and weaker in calm periods. Prior studies are in line with these findings Batten et al. (2010), Bentes (2022), suggesting that the volatility spikes are more intense and sharp under crisis periods. In particular, the recovery phase from the COVID-19 pandemic affects the interaction between the two metals in a volatile but smoother way, which is short-lived. Gil-Alana and Poza (2024) findings are also consistent with these results. The most significant correlation levels are observed in low frequencies due to the common macroeconomic factors that affect silver and platinum. Raza et al. (2023) also shows that in the long-term horizon, a symmetric behavior is observed in precious metals. Kucher and McCoskey (2017) reveals that the pairs of gold-silver and gold-platinum are co-integrated, but are unstable over time. The medium horizons exhibit a more cyclical pattern, and high frequencies present an unstable correlation. From the other side, during 1991-2020 Nekhili et al. (2021) found that the strongest correlations are shown in the medium term, while in the long term are weaker and insignificant. Hence, the author agreed with the higher correlation levels that metals reached during the pandemic. However, the dominant heatmaps reveal platinum's leading role at most timescales, despite Nekhili et al. (2021) for previous years shows that silver tends to act as a leader between the pair silver-platinum, especially in the medium and long horizons.

Therefore, the moderate correlation of returns is a result of different macroeconomic factors that affect each metal. As noted above, the behavior of platinum is more cyclical due to its dependence on industrial demand, while silver's character as a safe-haven asset creates sharper movements. Due to that, the high frequencies present transitory correlation, and the low frequencies exhibit stronger correlation values. Parnes and Parnes (2025) also agrees with the results of this study, focusing on the geopolitical risks that make the two metals vulnerable in the short-term periods. However, their financial character boosts the correlation long-term.

However, despite these findings providing meaningful insight about the relationship between silver and platinum, they could be extended. Firstly, future research can add macroeconomic and geopolitical variables (i.e., inflation expectations, monetary policy cycles) in the wavelet framework, providing a deeper understanding of the causes behind the structural break. Such extensions enrich the empirical literature on commodity co-movements and improve the efforts in making forecasts more accurate. Therefore, the addition of more precious metals, such as gold and palladium, can help to capture similar multi-scale correlation and leadership dynamics in a wider range of assets. So far, this method has been applied to energy and food commodities. An extension to this study could be the combination of wavelets with connectedness networks to capture which metals function as a transmitter or a receiver in the precious metals market. Secondly, the dominant heatmaps reveal the leader metal but do not provide evidence of causality. To detect this, causality tests would capture the direction of influence among precious metals during and after the pandemic. Precious metals presented various reactions over the last few years, where the exogenous shocks have increased, leading to further analysis.

6 Conclusions

This study investigates the dynamic relationship between silver and platinum futures prices for the time period between 02 February 2018 and 02 February 2025, providing detailed supply-demand analysis, descriptive statistics, correlation tables, and time-frequency econometrics methods. The focus was twofold: (i) to examine the price shifts of each metal across economic cycles, and (ii) to evaluate the level, persistence, and direction of their co-movement across different horizons using the Wavelet Local Multiple Correlation approach and Wavelet Coherence. The supply-demand analysis shows significant structural differences between the two markets. The silver market suffered from deficits in 2021 due to the pandemic, combined with the increasing demand from both investment and industry. The post-pandemic phase shows a smooth recovery for silver. Platinum, in contrast, is strongly tied to industrial demand, making it more vulnerable to exogenous shocks. Deficits have also appeared since 2022. The post-pandemic phase for the platinum market exhibits increasing deficits. Therefore, the minimum and the maximum values of raw prices during the sample period are as follows: platinum's lowest price reached 620 USD/oz in early 2020, while the highest level was around 1,280 USD/oz in 2021. The silver's lowest price was at 13-14 USD/oz in 2020, while the highest reached at 35 USD/oz in 2025. Thus, the descriptive statistics of daily log-returns indicate the properties of both markets as non-normally distributed, leptokurtic, and negatively skewed, meaning heavy tails and sensitivity to external shocks. The heightened silver's kurtosis also exhibits a higher tendency for extreme movements compared to platinum. The figure of daily silver and platinum log prices highlights their similar reactions to the pandemic. Both metal prices decreased during the pandemic due to mining closures and financial market stress, with the latter leading to panic selling and mass liquidation of silver investment holdings. Platinum prices were primarily affected by the sudden decline in industrial and automotive demand. In the post-pandemic period, platinum's behavior remains volatile due to concerns about industrial demand and supply constraints. At the same time, silver exhibits an upward trend, highlighting the increasing demand from both fields, which continues to drive prices higher. The plot of daily log-returns 8 indicates a usual - for financial return series - behavior. Volatility tends to be more concentrated and intense during crisis periods, specifically in early 2020, when both metals exhibit sharp spikes in both directions. However, the rapid shift from a sharp decline to recovery shows a speculative side (mainly for silver), as investor sentiment tends to drive prices more than changes in supply and demand. Simultaneously, the correlation analysis based on Kendall's and Pearson's coefficients indicated a moderate-to-strong positive relationship between returns. Pearson's correlation value was 0.58 ($p < 0.001$), while the Kendall correlation was approximately 0.39 ($p < 0.01$), reflecting their statistically significant co-movement. The scatterplot extends the analysis around their relationship, showing that in mid-term areas of daily changes, the pairs were strongly clustered along the regression line, revealing a stable co-movement. In the outlier areas, during stress periods, an asymmetry is observed. Platinum exhibits lower losses compared to silver. Despite both metals following the same direction, the intensity of silver's decline differs. However, the wide dispersion of points in the outliers shows that when silver presents sharper declines, platinum deviates from the expected trend. Before applying the time-frequency analysis, the stationarity of both silver series is examined. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are used. The results show that the log prices of platinum are stationary, while the log prices of silver are not. First differences are used to ensure stationarity. Both series are stationary in log-returns. Wavelet power spectrum plots for silver and platinum returns are used to show how the variances are distributed in different frequencies over time. Both returns have intense variance during the pandemic and at most frequencies, especially in the medium and long-term scales. In the post-pandemic period, silver's variance episodes are more concentrated in the medium term due to its financial character, while platinum was more scattered at short-term intervals. The findings of the analysis using WLMC reveal significant information about the interaction between the two metals. The multiscale correlation of returns shows a consistently positive but time-varying relationship across the entire sample period and frequency levels. In high frequencies (2-4], (4-8], and (8-16] time scales, the co-movement holds a moderate, positive level due to different reactions. During the COVID-19 pandemic in 2020, their relationship was slightly affected. Moving to the medium frequencies (8-16], (16-32], and (16-32] days, the correlation is characterized by cyclical patterns, pointing out that the two metals follow common economic cycles, mainly due to the strong dependence of platinum on industrial demand. In the [16-32] day band, the correlation peak was at 0.80 in 2020, and softened to 0.60 in late 2021, with a rebound in 2023. In the (32-64] day band, correlation experienced the most cyclical pattern over 2018-2022 and across all time-scales, as the peaks appeared in 2020,2022, and near 2025, while lower values are observed in 2018, 2021, and 2023. In low frequencies (128-256] and the Smooth component, correlation became stronger and less cyclical, as the only drop is noted during 2020-2022. The Smooth component underscores the general long-term trend of correlation. The correlation of volatility shows a similar behavior but with differences in the post-pandemic period. In short-term periods, the two metals are partially synchronized; however, with a positive degree. The medium-term periods reflect the adjustment phase, where the short-term noises have faded. The peak was observed in 2020, which was expected due to high variance in the metal market, while the decline was steep for the following years. Previous studies found that during crisis periods, the volatility between precious metals tends to strengthen, but weaken during recovery phases. In long-term periods, the volatility of silver and platinum is perfectly aligned before and during the pandemic, with values reaching 1.00; however, there are decreases in the following years. The Smooth component also shows a perfectly synchronized co-movement, confirming the existence of an enduring structural link between the metal's volatility. This work also employed dominant correlation heatmaps to demonstrate the leading role in their relationship. Platinum in both returns and volatility heatmaps is the dominant variable, meaning the most dependent in their relationship. In the returns, platinum emerges as the dominant asset, indicating that its price dynamics explain the joint relationship more effectively than silver alone. In volatility, platinum exhibits stronger synchronization with the joint volatility dynamics of the system across most years and timescales, while silver shows more abrupt and short-lived volatility episodes. Overall, the dominance results reveal that platinum consistently reflects common dynamics of the silver-platinum relationship in both returns and volatility, highlighting its roles as the primary dependent variable in terms of the WLMC framework.

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