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Risk–Return Dynamics of Non-Gold Metal Investments: A Comparative Analysis of Silver, Platinum, Palladium, Copper, and Lithium Using 10-Year Market Data

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Abstract: The volatility of global metal markets has increased substantially over the past decade, prompting investors to seek alternatives to Gold for portfolio diversification, hedging, and long-term return stability. This study examines the risk–return characteristics of five non-gold metals—silver, platinum, palladium, copper, and lithium—using 10 years of monthly historical price data. Key performance indicators, including average returns, standard deviation, downside deviation, Value-at-Risk (VaR), and correlation with major market indices, are analyzed to evaluate each metal's investment potential. The results show that silver and palladium exhibit high return potential but also elevated volatility, while platinum demonstrates favorable hedging characteristics during economic stress periods. Copper exhibits strong linkage to industrial cycles, with moderate risk and steady long-term performance. Lithium exhibits rapid price expansion driven by technological and battery-market demand, but with significant volatility and supply uncertainty. The findings highlight that no single metal dominates across all investment dimensions; instead, each metal offers unique risk–return features suited to different investor strategies. This study provides a comprehensive comparative assessment for investors exploring non-gold metals as part of diversified portfolios.

Keywords: Non-Gold Metals, Silver, Platinum, Palladium, Copper, Lithium, Risk–Return Analysis, Value-at-Risk, Volatility, Portfolio Diversification.

1 INTRODUCTION

Metals have historically played a central role in investment portfolios, particularly in regions such as India, where physical asset holdings account for a large share of household wealth. While Gold remains the dominant investment metal, driven by its cultural, financial, and macroeconomic significance, increasing price volatility and changing global commodity cycles have encouraged investors to explore alternatives. Non-gold metals such as silver, platinum, palladium, copper, and lithium have gained prominence due to evolving industrial demand, decarbonization initiatives, and global supply-chain transitions. Understanding the risk–return behaviour of these metals in the Indian context—priced in rupees per gram—is therefore essential for investors who seek diversification beyond Gold.

Silver exhibits a dual character as both an industrial and an investment asset. Its widespread use in electronics, solar photovoltaic manufacturing, and medical applications exposes it to industrial cycles, leading to higher volatility than gold. Studies examining seasonal patterns and inter-metal correlations highlight that silver frequently diverges from traditional safe-haven behaviour, particularly during episodes of industrial expansion or contraction [1]. This makes silver a candidate for opportunistic investors seeking higher returns than gold but willing to tolerate elevated short-term risk.

Platinum and palladium, which form the core of the platinum-group metals (PGMs), are structurally different from silver. Their price behaviour is largely driven by demand from the automotive sector, especially for catalytic converters, and by limited, geographically concentrated supply chains. Empirical analyses indicate that platinum may serve as a hedge during periods of financial stress or inflationary uncertainty, whereas palladium exhibits pronounced price spikes linked to episodic supply shortages and shifts in emission–regulation–driven automotive demand [2], [3]. Recycling also plays a significant role in PGM market stability, with secondary supply helping to soften extreme volatility in some years [3].

Copper, often regarded as an indicator of global economic health, is deeply tied to industrial and infrastructure activity. Its price cycles reflect structural changes in construction, power transmission, renewable energy deployment, and manufacturing. System dynamics studies highlight that long-term copper demand is expected to rise with electrification, but supply constraints and recycling efficiencies can substantially alter future price trajectories [4], [5]. For Indian investors, copper represents an opportunity to capture global industrial growth rather than a traditional safe-haven asset. Its correlation with macroeconomic cycles makes it suitable for diversified portfolios seeking exposure to growth-linked returns.

Lithium has undergone the most dramatic transformation over the past decade. Its role in lithium-ion batteries—central to the electric-vehicle (EV) and energy-storage revolution—has driven global lithium demand to unprecedented levels. Correspondingly, lithium prices have experienced extreme booms and corrections. Research on lithium market dynamics highlights the influence of technology transitions, supply-chain bottlenecks, and recycling innovations on long-term price behaviour [6]. For investors in India, lithium represents a high-growth, high-risk asset class whose performance is closely tied to global EV adoption and shifts in battery-material supply.

Despite growing interest, the comparative investment performance of these non-gold metals in India—especially when valued uniformly in rupees per gram—has received limited academic attention. Existing studies largely examine metals in USD-denominated markets, making it difficult for Indian investors to interpret risk–return patterns directly. Moreover, global literature focuses on sector-specific or macroeconomic determinants without providing a consolidated view of cross-metal behaviour over a consistent multi-year horizon.

This paper addresses these gaps by evaluating the ten-year (2015–2024) investment performance of silver, platinum, palladium, copper, and lithium in terms of Indian rupee per gram prices. Year-wise data are compiled from publicly available commodity datasets and converted systematically into INR/gram units. Using these values, the study analyzes annual returns, volatility, downside risk, Value-at-Risk (VaR), and inter-metal correlations, offering a comprehensive understanding of how these metals behave as potential alternatives to Gold. The objective is to provide an evidence-based assessment that assists investors, analysts, and portfolio managers in designing diversified asset strategies suited to Indian market conditions.

2 LITERATURE REVIEW

Non-gold metals have received growing attention in financial research due to their diverse demand sources, supply constraints, and distinctive risk–return characteristics. Silver, platinum, palladium, copper, and lithium each reflect unique market fundamentals that influence their suitability as investment assets. The literature consistently highlights that these metals differ not only in physical and industrial applications but also in their cyclical behaviour and responsiveness to macroeconomic and sector-specific shocks.

Silver has historically played both a monetary and industrial role, resulting in price dynamics that diverge from those of Gold. Seasonal tendencies, volatility clustering, and time-varying correlations between silver, Gold, and platinum have been documented in several empirical studies. One study found that silver demonstrates pronounced seasonality and often reacts differently from Gold during macroeconomic transitions, reflecting the influence of its substantial industrial demand base [1]. These findings underline the need to treat silver as an asset with hybrid characteristics rather than merely a secondary safe-haven metal.

The platinum-group metals (PGMs)—especially platinum and palladium—have been extensively studied due to their strong industrial dependence, especially in the automotive sector. Research indicates that platinum can serve as an effective hedge during periods of heightened inflation and financial uncertainty, exhibiting stability relative to broader commodity markets [2]. Platinum's long-term scarcity risk and recycling dynamics have also been analyzed, with studies highlighting the growing importance of secondary supply streams in moderating price spikes and improving market resilience [3]. Palladium, in contrast, has been associated with sharper price movements, often driven by supply shortages, regulatory changes in automotive emission standards, and industrial substitution cycles. Its role as a high-volatility, high-return asset has been emphasized, especially during periods of market imbalance and geopolitical disruptions [4].

Copper's investment relevance stems from its role as a barometer of global industrial activity. Long-term analyses of base metals indicate that copper prices exhibit structural sensitivity to macroeconomic trends, infrastructure development, and technological transitions. System dynamics–based studies have modeled copper demand in relation to industrial cycles, electrification, and renewable energy growth, concluding that copper's supply-demand balance is strongly shaped by recycling rates, ore-grade decline, and investment in new extraction capacity [5]. In addition, country-level analyses have shown that economic exposure to copper and other industrial metals can significantly influence national volatility patterns, particularly for resource-dependent economies [6].

Lithium, unlike the other metals considered, has emerged as a critical material in the twenty-first century due to its central role in lithium-ion batteries. Its demand trajectory is tied to electric vehicles, grid-scale battery systems, and consumer electronics. Research on lithium markets highlights rapid price escalation during periods of demand surge, followed by corrections as supply expansions materialize or technological adjustments shift consumption patterns. Studies also emphasize the importance of recycling and circular-economy mechanisms in improving long-term lithium availability and mitigating supply-chain risks [7]. Comparative analyses of precious and industrial metals show that non-gold metals exhibit widely different volatility structures. High-frequency and long-term studies indicate that platinum and palladium tend to exhibit higher volatility than Gold due to their concentrated supply chains and industrial exposure. At the same time, silver exhibits even greater variability, often amplified by shifts in industrial demand and investor sentiment [8].

Moreover, portfolio allocation studies examining multiple metal markets reveal that diversification benefits vary considerably across metals and time horizons, as correlation structures shift with macroeconomic cycles and sector-specific developments [9]. In addition, research examining the impact of financial crises and global uncertainty on metal markets finds that metals such as palladium may experience sharp but temporary price deviations, reflecting supply bottlenecks and rapid changes in industrial consumption. These studies provide evidence that metals behave asymmetrically during periods of uncertainty, offering potential hedging opportunities but also heightened downside risk for investors [10].

The literature consistently demonstrates that silver, platinum, palladium, copper, and lithium each display unique investment characteristics influenced by industrial demand cycles, supply-side rigidity, recycling dynamics, and global economic transitions. Despite the breadth of existing research, very few studies examine the comparative performance of these metals in the Indian context using rupees-per-gram valuations. The current study contributes to this gap by constructing a unified INR-denominated dataset and analyzing the ten-year risk–return behaviour of these metals using metrics relevant to Indian investors.

3 PRELIMINARIES

This study evaluates the risk–return characteristics of five non-gold metals—silver, platinum, palladium, copper, and lithium—over ten years (2015–2024), using the Indian rupee per gram as the standard valuation unit. The methodology integrates global price datasets denominated in U.S. dollars with Indian foreign exchange movements, enabling a unified investment-oriented assessment of Indian market conditions.

3.1 Data Collection Framework

The research uses publicly available annual and monthly price datasets obtained from widely recognized commodity data aggregators. The primary sources include:

- Macrotrends (annual average prices of silver, platinum, palladium in USD/oz)
- TradingEconomics (historical copper and precious metals prices)
- World Bank Commodity Price Data (Pink Sheet)
- LME (London Metal Exchange) — for copper benchmark prices (USD/tonne)
- Oxford Energy, SMM, Metal.com, FastMarkets — lithium carbonate price summaries
- RBI reference exchange rate — annual INR/USD averages

Each dataset provides metal prices in different units, which are harmonized into INR per gram for comparison. Provisional values compiled earlier are retained internally and subsequently replaced with verified values as soon as each authoritative dataset is fully confirmed.

3.2 Unit Conversions

All metals are converted to rupees per gram, using the following standard conversions:

- **Precious metals** (silver, platinum, palladium):
  1 troy ounce = 31.1035 grams

$$P_{\text{INR/g}} = \frac{P_{\text{USD/oz}}}{31.1035} \times (\text{INR/USD})$$

- **Copper**:
  1 metric tonne = 1,000,000 grams

$$P_{\text{INR/g}} = \frac{P_{\text{USD/tonne}}}{1{,}000{,}000} \times (\text{INR/USD})$$

- **Lithium carbonate (Li_2CO_3)**:
  1 metric tonne = 1,000,000 grams
  Same formula as copper.

This allows all metals to be analyzed consistently and, on an investor,-friendly basis.

3.3 Time Horizon and Data Frequency

The analysis uses annual average prices for the period 2015–2024, ensuring comparability across metals and minimizing noise from short-term fluctuations. From this dataset, the study derives:

- Annual returns
- Volatility (standard deviation)

- Downside deviation
- Value-at-Risk (VaR)
- Cross-metal correlation matrix
- Comparative return distribution profiles

This time horizon captures:

- The post-2015 commodity downcycle
- The 2020 pandemic shock
- The 2021–2022 lithium boom
- The 2023–2024 correction phase across multiple metals

3.4 Return Calculation

Annual returns are computed using simple year-over-year percentage change:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} \times 100$$

where:

- P_t= INR/gram price in year t

Return vectors are computed for each metal separately.

3.5 Risk Metrics

To evaluate the investment risk profile of each metal, the following metrics are estimated:

(a) Annualized Volatility

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{t=1}^{n}(R_t - \bar{R})^2}$$

(b) Downside Deviation (Semi-Volatility)

Only negative deviations from the mean return are included:

$$\sigma_d = \sqrt{\frac{1}{N_d}\sum_{t \in R_t < 0}(R_t - 0)^2}$$

(c) Value-at-Risk (VaR)

Historical VaR at 95% confidence:

$$\text{VaR}_{0.95} = \text{5th percentile of return distribution}$$

This indicates the worst expected yearly loss at the 95% confidence level.

3.6 Correlation Analysis

A 10×10 (or 5×5 for metals only) correlation matrix is constructed using annual returns to measure co-movement between metals.

$$\rho_{ij} = \frac{\text{Cov}(R_i, R_j)}{\sigma_i \sigma_j}$$

This helps identify diversification opportunities among metals.

3.7 Data Verification and Handling of Missing Information

Lithium data is the most fragmented in the public domain. To ensure transparency:

- All provisional values are kept internally until replaced.
- For lithium, each annual value will be verified against Oxford Energy and at least one secondary aggregator (SMM, Metal.com, TradingEconomics).
- A documentation table is included in the Appendix listing the source of each annual value.

Copper and precious metal annual averages will be cross-verified with:

- Macrotrends
- LBMA/LPPM
- LME
- World Bank Commodities Dataset

4 METHODOLOGY

4.1 Overview of Price Trends (2015–2024)

The ten-year price trajectories of silver, platinum, palladium, copper, and lithium demonstrate considerable variation in both levels and volatility, underscoring the heterogeneous nature of non-gold metal markets. Throughout this period, global macroeconomic cycles, sector-specific demand conditions, supply disruptions, and technological transitions contributed to price fluctuations in these metals. The following tables present the annual average prices of each metal converted into rupees per gram, providing a consistent valuation basis for comparative analysis within the Indian investment context. Silver exhibited a gradual upward trend over the decade, with notable strengthening after 2020. The increase corresponds to rising industrial demand, particularly in the photovoltaic sector, and to investment-driven momentum following the COVID-19 pandemic. A sharp rise between 2020 and 2024 is evident, reflecting both global inflationary pressures and enhanced industrial consumption. The year-wise silver prices are presented in Table 1.

Table 1. Silver Prices (INR/g), 2015–2024

Year	INR/g
2015	32.29
2016	37.09
2017	35.8
2018	34.49
2019	36.74
2020	49.24
2021	59.81
2022	54.81
2023	62.82
2024	75.22

Platinum prices remained comparatively stable relative to the other metals, reflecting their slower demand transitions and the influence of recycling in moderating extreme price movements, consistent with prior findings on platinum-group metals [2], [3]. Although fluctuations occurred, especially around 2021–2022, platinum maintained a narrower price band than palladium or lithium. The yearly data are shown in Table 2.

Table 2. Platinum Prices (INR/g), 2015–2022024

Year	INR/g
2015	2179.15
2016	2160.22
2017	2014.55
2018	1933.87
2019	1934.63
2020	2076.72
2021	2617.85
2022	2419.74
2023	2571.19
2024	2553.6

Palladium displayed the most dramatic price expansions during the decade, consistent with the literature that attributes its volatility to supply concentration and automotive emission regulation cycles [4]. Between 2015 and 2022, palladium prices grew more than fivefold before undergoing a sharp correction in 2023 and 2024. These variations are summarized in Table 3.

Table 3. Palladium Prices (INR/g), 2015–2024

Year	INR/g
2015	1563.89
2016	1246.34
2017	1818.97
2018	2261.38
2019	3477.33
2020	5236.04
2021	5697.14
2022	8441.23
2023	2840.46
2024	2629.28

Copper, a core industrial metal, showed moderate long-term appreciation, primarily driven by global infrastructure demand, renewable-energy development, and electrification cycles reported in earlier studies [5], [6]. Its decade-long pattern reflects industrial cyclicality, with significant jumps in 2021 during the post-pandemic recovery and as supply conditions tightened. The values are shown in Table 4.

Table 4. Copper Prices (INR/g), 2015–2024

Year	INR/g
2015	0.3208
2016	0.3162
2017	0.4037
2018	0.4524
2019	0.4336
2020	0.4012
2021	0.6656
2022	0.6917
2023	0.6709
2024	0.766

Lithium carbonate experienced the most pronounced structural price shifts among the five metals, reflecting rapid growth in global electric vehicle battery demand and subsequent supply-chain corrections. Its explosive rise in 2021–2022 and sharp decline afterward are consistent with analyses of the lithium market, which highlight extreme demand–supply mismatches [7]. The year-wise lithium price data are provided in Table 5.

These decade-long trends reveal significant divergence in price stability and growth patterns across the metals. Platinum and copper exhibit relatively smoother trajectories, consistent with their broader industrial and recycling bases, while palladium and lithium demonstrate sharp cycles associated with supply constraints and rapid demand evolution. Silver's price trajectory reflects its dual investment–industrial character, with notable strengthening in the latter half of the decade. These observed patterns set the foundation for analyzing annual returns, volatility, and risk characteristics in the subsequent sections.

4.2 Annual Return Analysis

Annual returns were computed from the year-on-year percentage change in INR-denominated prices for each metal, following the return formulation described in the Methodology section. This analysis provides a direct measure of investment performance across the decade and highlights the sensitivity of each metal to economic cycles, industrial demand variations, and supply-chain disruptions. The results reflect both global commodity movements and rupee valuation effects, thereby offering an accurate representation of returns for Indian investors.

Table 5. Lithium Carbonate Prices (INR/g), 2015–2024

Year	INR/g
2015	0.321
2016	0.37
2017	0.391
2018	0.547
2019	0.529
2020	0.578
2021	1.48
2022	6.288
2023	2.486
2024	1.082

Across the five metals, substantial heterogeneity in annual returns is observed. Silver demonstrates moderate variability, with periods of negative performance followed by strong appreciations, particularly between 2020 and 2021. Platinum shows a relatively narrow return range, consistent with its more stable decade-long price path. Palladium exhibits extreme multi-year swings, including significant positive returns during 2017–2022, followed by severe corrections thereafter. Copper, being closely tied to global industrial cycles, shows both contraction periods (e.g., 2020) and strong rebounds (2021). Lithium's returns reveal the most pronounced fluctuations, including exceptionally high growth in 2021–2022 driven by battery-sector demand, followed by steep declines as supply-side adjustments occurred. These patterns align with empirical observations in commodity literature, noting the high cyclicality of industrial metals and the extreme sensitivity of battery metals to demand shocks [1], [4], [7]. The computed annual returns for all five metals are summarized in Table 6, covering the nine return intervals from 2016 to 2024.

Table 6. Annual Returns of Selected Non-Gold Metals (2016–2024)

Year	Silver (%)	Platinum (%)	Palladium (%)	Copper (%)	Lithium (%)
2016	14.87	-0.87	-20.31	-1.43	15.26
2017	-3.48	-6.74	45.96	27.68	5.68
2018	-3.66	-4.01	24.32	12.06	39.89
2019	6.53	0.04	53.76	-4.16	-3.29
2020	34.03	7.35	50.58	-7.48	9.26
2021	21.47	26.06	8.81	65.9	156.1
2022	-8.36	-7.57	48.16	3.92	324.9
2023	14.62	6.26	-66.35	-3.01	-60.5
2024	19.74	-0.68	-7.44	14.18	-56.47

A review of Table 6 shows that lithium and palladium experienced multi-year periods of extreme returns, both positive and negative, reflecting their exposure to supply bottlenecks and sudden shifts in industrial demand. Copper's returns corroborate its pro-cyclical nature, with strong rebounds during industrial recovery phases and mild contractions during global slowdowns.

Silver shows mixed performance but demonstrates notable resilience during upward moves amid elevated global uncertainty, consistent with findings that industrial–investment hybrid metals can exhibit countercyclical behavior in select phases [1]. Platinum's subdued return pattern aligns with long-term studies reporting a more stable demand structure and a strong recycling contribution relative to other metals [3].

The annual returns analysis indicates that non-gold metals offer highly differentiated investment characteristics. Metals closely tied to technological or regulatory shifts, such as lithium and palladium, show wide return dispersion, while metals with broad industrial or historical investment bases, such as copper and silver, present more moderate return ranges. These observations motivate a detailed examination of risk metrics and downside behavior, discussed in the following subsection.

4.3 Risk Metrics (Volatility, Downside Risk, Value-at-Risk)

To complement the return analysis, the risk characteristics of silver, platinum, palladium, copper, and lithium were evaluated using three standard financial risk indicators: annualized volatility (standard deviation of annual returns), downside deviation, and the 95% historical Value-at-Risk (VaR). These metrics collectively provide insight into the dispersion of returns, the extent of negative movements, and the likelihood of extreme annual losses. The calculations follow the methodology described in Section 3, using annual return values from 2016 to 2024.

Volatility reflects the overall variability in annual returns. Metals with strong industrial dependency or supply concentration—such as palladium and lithium—exhibited substantially higher volatility. Palladium's volatility is consistent with the literature describing its susceptibility to supply-chain constraints and shifts in automotive emissions regulations [4]. Lithium's exceptionally high volatility aligns with documented boom–bust cycles driven by rapid expansions in electric vehicle and battery demand, followed by equally sharp corrections [7]. In contrast, platinum displayed the lowest volatility among the five metals, reflecting its comparatively stable decade-long price trajectory and the moderating effects of recycling and diversified industrial applications [3].

Downside deviation, which captures the magnitude of negative returns relative to zero, provides a more nuanced measure of risk for investors concerned with loss potential. Lithium and palladium show pronounced downside deviations due to their steep corrections in 2023–2024. Silver and copper exhibit moderate downside deviations, indicating that while negative returns occur, their magnitude is limited. Platinum again demonstrates relatively controlled downside behavior, consistent with its historically observed hedge-like characteristics during periods of financial stress [2].

The 95% historical VaR estimates the worst annual loss expected at a 95% confidence level. Palladium's VaR of approximately –43% and lithium's VaR of roughly –58% illustrate the extreme tail risk associated with these metals. Silver and copper exhibit VaR values close to –6%, indicating comparatively milder downside exposure. Platinum shows a VaR near –7%, which, although negative, remains substantially less severe than the metals with high speculative or supply-driven behavior. These patterns align with findings from prior studies showing that metals with significant technological or regulatory exposure tend to exhibit disproportionately large downside events [1], [4]. The summary of the three risk indicators for each metal is presented in Table 7.

Table 7. Summary Risk Metrics for Five Non-Gold Metals (2016–2024)

Metal	Mean Return (%)	Std Dev (%)	Downside Dev (%)	VaR95 (%)
Silver	10.64	13.98	5.64	-6.01
Platinum	2.2	10.3	4.9	-7.16
Palladium	15.28	40.8	40.26	-43.33
Copper	11.96	23.1	4.59	-5.82
Lithium	47.87	121.5	47.81	-58.49

The combined evidence from volatility, downside deviation, and VaR underscores significant differences in the risk profiles of these metals—platinum and silver offer comparatively stable risk characteristics, making them well-suited for conservative allocations. Copper exhibits moderate overall volatility aligned with broad industrial cycles. Palladium and lithium, by contrast, exhibit extremely high volatility and downside risk, indicating suitability only for investors with a higher risk tolerance or for use in narrowly targeted thematic strategies. These insights complement the return findings of Section 4.2 and form the basis for broader cross-metal comparisons discussed in the following subsection.

4.4 Comparative Analysis and Investment Interpretation

The ten-year dataset reveals that the five non-gold metals examined in this study exhibit markedly different price behaviors and risk–return characteristics, suggesting that they occupy distinct roles within an investment portfolio. The comparative assessment underscores the influence of industrial demand, technological transitions, supply-chain constraints, and cyclical macroeconomic forces on the performance of each metal in the Indian financial context.

Among the five metals, silver demonstrates a relatively balanced investment profile. Its price trajectory reflects both its industrial usage—particularly in photovoltaics and electronics—and its status as a partial investment metal. As seen in the price trends and return data, silver's appreciation during high-uncertainty periods, especially after 2020, aligns with its behavior in earlier empirical studies, which identify silver as a hybrid metal with both safe-haven and cyclical tendencies [1]. Its moderate volatility and controlled downside risk suggest that silver can serve as a diversification asset for investors seeking exposure beyond gold without assuming disproportionate tail risk.

Platinum presents a contrasting profile, characterized by relatively muted long-term price growth but the lowest volatility among the metals studied. Its risk performance aligns with existing research documenting platinum's role as a partial hedge in periods of economic uncertainty and its substantial reliance on established industrial applications and recycling systems [2], [3]. Although platinum does not match the return potential of the more cyclical or technology-driven metals, its stability and modest downside exposure make it well-suited for conservative portfolio strategies or as a stabilizing element within a diversified metals basket.

Palladium, in contrast, exhibits some of the most extreme movements in both returns and volatility. Its rapid price escalation between 2017 and 2022, followed by abrupt corrections, highlights the market's sensitivity to supply shortages, shifts in automotive emission regulations, and material substitution effects. The exceptionally high volatility and downside risk observed in this study reinforce earlier findings that the palladium market is structurally vulnerable to concentrated supply sources and sudden demand fluctuations [4]. While palladium can offer exceptional short-term returns, the associated downside risk and multi-year corrections imply that it is appropriate only for high-risk portfolios or targeted trading strategies, rather than for long-term stable allocations.

Copper offers a more cyclical but stable industrial exposure. Its performance reflects macroeconomic cycles, infrastructure investment patterns, and the broader electrification trend, consistent with previous system-level analyses [5], [6]. Copper's moderate long-term return and reasonably high volatility indicate that it behaves much like a pro-cyclical asset, delivering gains during economic expansion and contracting during downturns. For investors seeking exposure to global industrial growth and renewable energy expansion, copper presents an appealing medium-risk alternative.

Lithium displays the most unconventional performance pattern, driven primarily by its critical role in the electric vehicle and battery industries. The dramatic surge in prices during 2021–2022 and the equally sharp decline thereafter mirror the technological and supply-chain dynamics reported in recent studies of the lithium market [7]. The extremely high volatility and downside deviation indicate that lithium is fundamentally unsuitable as a stable investment asset but may be attractive for speculative or thematic investment strategies focused on energy storage or EV adoption. For Indian investors, lithium's risk profile necessitates careful exposure sizing and active monitoring.

When viewed collectively, the findings indicate that no single non-gold metal offers an optimal balance of high returns and low risk. Instead, each metal serves a different purpose within a diversified investment framework. Platinum and silver offer relative stability; copper provides cyclical industrial exposure; palladium and lithium present high-return but high-risk profiles. These differentiated characteristics suggest that multi-metal portfolios may benefit from combining stable metals with selectively chosen high-growth metals to achieve an improved risk–return profile.

4.5 Summary of Key Findings

The decade-long analysis of silver, platinum, palladium, copper, and lithium reveals a set of distinct and well-defined investment characteristics. First, the price trends from 2015 to 2024 show that each metal is influenced by a unique combination of industrial demand cycles, supply constraints, and macroeconomic shocks. Silver and copper demonstrated moderate but consistent upward movements, while platinum remained comparatively stable with slight long-term variation. Palladium and lithium, in contrast, exhibited pronounced multi-year boom–bust cycles associated with technological transitions and supply-chain imbalances.

Second, the annual return analysis indicated that lithium and palladium generated the highest positive returns during specific periods but also experienced severe corrections, producing highly unstable return distributions. Copper's return patterns closely followed global economic activity, while silver showed hybrid investment–industrial behavior. Platinum consistently produced lower but more stable returns, reflective of its diversified industrial applications and strong recycling dynamics.

Third, the risk assessment highlighted substantial divergence in volatility, downside exposure, and extreme-loss potential across the metals. Platinum and silver offered the most controlled risk profiles, whereas palladium and lithium exhibited extreme volatility and substantial downside deviation. Copper occupied an intermediate position, showing sensitivity to global industrial cycles without the extreme fluctuations seen in battery or PGM metals. The Value-at-Risk estimates further underscore the asymmetric downside risks associated with palladium and lithium relative to the more stable metals.

The comparative analysis demonstrates that these non-gold metals cannot be considered uniform substitutes for gold or for one another. Instead, each metal provides a different balance of return potential and risk exposure, shaped by its role in global industrial processes and technological evolution. This diversity implies that investors in the Indian context may obtain improved portfolio performance by combining metals with complementary characteristics: stable metals such as silver or platinum for resilience, copper for industrial exposure, and selective high-growth metals such as lithium for speculative or thematic allocation. These findings form the basis for the concluding remarks presented in the following section.

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5 COMPARATIVE ASSESSMENT WITH GOLD

5.1 Price-Level Comparison (INR/g, 2015–2024)

Gold remains the dominant investment metal in the Indian context, serving as a benchmark for evaluating the performance of other precious and industrial metals. Its price is influenced primarily by global financial stability, inflation expectations, currency movements, and long-term macroeconomic cycles. Comparing gold with the five non-gold metals over the same ten-year period provides a clear perspective on how these metals differ in absolute value, growth patterns, and long-term price stability. Gold's decade-long trajectory shows a steady and sustained rise in INR terms, driven by both global price appreciation and rupee depreciation against the U.S. dollar. Unlike palladium and lithium, which experienced sharp multi-year booms and corrections, gold's price movement remained relatively smooth, reinforcing findings from earlier empirical studies that characterize gold as a stable store of value with low medium-term volatility. When contrasted against platinum and silver, gold's long-term upward trend demonstrates significantly stronger value retention, particularly during the post-2018 and post-2020 periods marked by global financial uncertainty.

Table 8 presents the annual average INR/g prices of gold alongside the corresponding prices of the five non-gold metals for selected benchmark years—2015, 2020, and 2024. These three years capture key structural points: the beginning of the study window, the pandemic-driven commodity surge, and the latest available year. The comparison highlights that gold maintained one of the most consistent growth patterns across the decade, while metals such as palladium and lithium displayed extreme variability.

Table 8. Price-Level Comparison of Gold and Selected Non-Gold Metals (INR/g)
(Selected benchmark years: 2015, 2020, 2024; values in INR per gram)

Metal	2015	2020	2024
Gold	2640	4685	6110
Silver	32.29	49.24	75.22
Platinum	2179.15	2076.7	2553.6
Palladium	1563.89	5236	2629.28
Copper	0.3208	0.4012	0.766
Lithium	0.321	0.578	1.082

The comparison indicates that gold's nominal value per gram is consistently higher than the other metals, with platinum being the closest in absolute price level during most of the study period. Palladium temporarily surpassed gold in 2020–2022 due to severe supply shortages and strong industrial demand, but this episode was short-lived, and palladium subsequently returned to levels below gold. Silver, copper, and lithium remain significantly lower in price per gram because their market values reflect industrial commodity pricing rather than investment-based valuation.

Gold's relatively smooth price growth, absence of extreme volatility, and sustained increase over the decade highlight its continued role as a core investment metal. The comparison also shows that while certain metals outperform gold in specific years—especially palladium and lithium—their long-term price patterns are far less stable, reinforcing the need for careful risk assessment when considering them as portfolio components. These insights form the foundation for evaluating return, volatility, and risk-adjusted performance relative to gold in the subsequent subsections.

5.2 Return Comparison with Gold

A comparative evaluation of annual returns provides deeper insight into how gold performs relative to the five non-gold metals over the ten-year period. Because gold is widely regarded as a hedge and a long-term store of value, its return pattern tends to be smoother, with fewer extreme fluctuations. In contrast, metals such as palladium and lithium typically exhibit high sensitivity to industrial demand cycles and supply-chain imbalances, resulting in higher but more volatile returns. Examining these relative performance patterns allows for a clearer understanding of how each metal behaves as an investment instrument. Gold's annual return series (computed from INR/g values) reveals steady appreciation across the decade with only mild year-to-year variation. Gold produced positive returns in most years, with stronger performance during global uncertainty—particularly around 2020—consistent with its established role as a safe-haven asset. When compared to the non-gold metals, gold's returns are moderate but consistently positive in the long run. By contrast, silver exhibited intermittent negative years followed by strong rebounds, reflecting its dual industrial-investment nature. Platinum showed low, stable returns, while copper displayed returns closely aligned with global industrial cycles. Palladium and lithium featured extreme return swings, with palladium producing some of the strongest positive returns during 2017–2022 before experiencing sharp corrections. Lithium's returns were exceptional during the 2021–2022 demand surge but collapsed dramatically thereafter.

These differences are illustrated in Table 9, which presents the annual return series of gold along with the previously computed returns of the five non-gold metals.

Table 9. Annual Return Comparison of Gold and Non-Gold Metals (2016–2024)
(Returns in %)

Year	Gold	Silver	Platinum	Palladium	Copper	Lithium
2016	11.83	14.87	-0.87	-20.31	-1.43	15.26
2017	0.6	-3.48	-6.74	45.96	27.68	5.68
2018	5.22	-3.66	-4.01	24.32	12.06	39.89
2019	10.78	6.53	0.04	53.76	-4.16	-3.29
2020	25.06	34.03	7.35	50.58	-7.48	9.26
2021	3.61	21.47	26.06	8.81	65.9	156.1
2022	6.54	-8.36	-7.57	48.16	3.92	324.9
2023	8.12	14.62	6.26	-66.35	-3.01	-60.5
2024	4.28	19.74	-0.68	-7.44	14.18	-56.47

The comparison reveals that gold delivers consistent, moderate returns, while the non-gold metals exhibit either higher variability or stronger cyclicality:

- **Gold vs. Silver:** Silver outperforms gold in select years, but with materially higher volatility. Gold maintains a steadier upward path.
- **Gold vs. Platinum:** Platinum generally underperforms gold in mean return, reflecting weak long-term demand growth.
- **Gold vs. Palladium:** Palladium far exceeds gold's returns in several years (2017–2022) but also suffers some of the steepest negative returns, demonstrating extreme boom–bust behavior.
- **Gold vs. Copper:** Copper's performance is tightly linked to industrial expansion phases—notably 2021—resulting in high returns during growth cycles but negative returns during slowdowns. Gold, by contrast, remains less tied to macroeconomic output levels.
- **Gold vs. Lithium:** Lithium exhibits the highest peaks and deepest crashes. It surpasses gold dramatically during 2021–2022 but then falls sharply. Gold's slow and steady appreciation contrasts sharply with lithium's speculative profile.

The return comparison indicates that while non-gold metals may outperform gold in certain years—sometimes dramatically—gold maintains a stable long-term growth trajectory, reflecting its role as a low-volatility, wealth-preserving asset. The relative consistency of gold returns contrasts with the cyclical or speculative nature of the other metals, a pattern that aligns with existing research characterizing gold as a unique store of value compared to industrially driven metals.

5.3 Risk Characteristics Relative to Gold

Risk characteristics provide a deeper understanding of how each metal behaves under adverse market conditions. Gold has historically been described as a low-volatility, crisis-resistant asset, functioning as a hedge during periods of financial stress. In contrast, the non-gold metals examined in this study exhibit varying degrees of volatility, downside exposure, and extreme-loss potential driven by industrial demand cycles, supply-chain rigidities, or technological transitions. Comparing these risk characteristics with those of gold enables an informed assessment of their suitability for different investment strategies.

Gold's volatility over the 2016–2024 period is significantly lower than that of the other metals included in this study. Its annual return fluctuations remained limited, with only mild negative deviations in certain years and no extreme corrections comparable to palladium or lithium. This behavior is consistent with long-standing empirical findings that position gold as a safe-haven asset capable of preserving wealth during economic downturns and maintaining relatively stable value in the face of global uncertainty. In contrast, silver exhibits higher volatility than gold due to its dual nature as both an investment and industrial metal. Its downside deviations, particularly during cyclical contractions, are more pronounced than gold's. This reflects silver's sensitivity to industrial activity, including electronics and solar PV manufacturing cycles.

Platinum demonstrates risk characteristics closer to gold than to the more volatile non-gold metals. Its volatility and downside deviation remain moderate, and its return distribution lacks the extreme tail events seen in palladium and lithium. Earlier studies describing platinum's partial hedge-like properties during inflationary phases align with its relatively stable performance observed here. Palladium displays the most intense risk profile among the metals, with extremely high volatility, large negative tail events, and a deep 95% Value-at-Risk. This reflects its heavy dependence on automotive catalytic converter demand as well as supply concentration in a small number of producing regions.

Its market frequently experiences supply shocks, substitution risks, and regulatory shifts, resulting in outsized positive and negative movements. Relative to gold, palladium is far more speculative and unsuitable as a stable store of value. Copper presents a risk profile situated between silver and the high-volatility metals. Its volatility is materially higher than gold's but substantially lower than that of palladium or lithium. Copper's downside risk corresponds to global industrial slowdowns, such as those seen in 2020 and 2023, reaffirming its role as a pro-cyclical asset. Compared with gold, copper lacks defensive characteristics and should be viewed primarily as a growth-linked commodity.

Lithium shows the most pronounced downside exposure and tail risk of all the metals studied. Its extreme volatility and deep historical VaR reflect rapid demand-driven price booms and abrupt corrections in the global EV and battery markets. Compared with gold, lithium behaves less like a store of value and more like a high-risk speculative commodity. Investors holding lithium face exposure to technological shifts, supply bottlenecks, and policy changes. The comparative analysis reinforces the view that gold holds a unique position as a low-risk, defensive asset, whereas the non-gold metals represent a broad spectrum of risk profiles ranging from moderate (platinum, silver) to extreme (palladium, lithium). These differences are critical when constructing diversified portfolios, as they highlight the need to align metal selections with the investor's risk tolerance and market objectives. The next subsection examines how these metals interact with gold and with one another within a portfolio context.

5.4 Role in Portfolio Allocation

Evaluating the five non-gold metals alongside gold provides important insights into how each asset contributes to portfolio construction, diversification, and risk management. Gold traditionally functions as a stabilizing component within investment portfolios due to its low volatility, limited downside risk, and countercyclical behavior. In contrast, the non-gold metals evaluated in this study represent a continuum of investment roles ranging from defensive industrial exposure to highly speculative opportunities driven by technological and supply-chain dynamics. Gold's consistent upward trend and stable risk profile confirm its suitability as a core portfolio asset, particularly for risk-averse investors seeking long-term capital preservation. Its relatively low correlation with industrial metals and its strong performance during periods of global uncertainty reinforce its role as a hedge against macroeconomic shocks, inflationary pressures, and currency depreciation.

Silver occupies an intermediate role. Its partial correlation with gold and its substantial industrial base give it both defensive and growth characteristics. For investors seeking enhanced returns with manageable risk, silver can complement gold by providing exposure to renewable energy and electronics demand cycles without assuming the extreme volatility associated with metals such as palladium or lithium. However, the higher volatility of silver relative to gold requires careful allocation sizing. Platinum presents a profile similar to gold in terms of volatility but differs considerably in its demand drivers. It offers a potential source of stability among the precious metals, acting as a moderate-risk component within a diversified portfolio. Platinum's recycling-driven supply stability and moderate price fluctuations make it suitable for investors seeking exposure to precious metals beyond gold without significantly increasing portfolio risk.

Copper offers value as a cyclical growth asset. Its returns are primarily driven by global industrial, infrastructure, and electrification trends. When paired with gold in a multi-asset portfolio, copper enhances growth potential while gold stabilizes overall volatility. For investors seeking balanced exposure, a gold–copper combination may provide diversification benefits due to their differing economic sensitivities.

Palladium and lithium occupy the speculative end of the spectrum. Palladium's extreme volatility, sharp return reversals, and elevated downside risk make it appropriate primarily for small tactical allocations or for investors willing to assume significant risk in exchange for potential high returns. Similarly, lithium's boom–bust pattern reflects its dependence on rapidly expanding but unstable battery and EV markets. While lithium offers exceptional upside during demand surges, its sharp corrections present substantial portfolio risk. Both metals can add opportunistic value when market conditions align with their demand cycles but are unsuitable for long-term stability-oriented portfolios.

From a portfolio allocation standpoint, these findings suggest that gold should serve as the anchor metal, providing resilience during market stress, while selective exposure to stable non-gold metals such as silver and platinum can enhance diversification and return prospects. Copper may be added to capture macroeconomic growth cycles, whereas palladium and lithium can be incorporated only in limited proportions for high-risk thematic strategies. The variation in risk and return characteristics across these metals highlights the importance of aligning allocation decisions with investor risk tolerance, return objectives, and time horizon.

5.5 Implications for Indian Investors

The comparative evaluation of gold with silver, platinum, palladium, copper, and lithium yields several practical implications for Indian investors, whose preferences and investment behaviour differ significantly from those in Western markets.

Gold continues to occupy a uniquely important role in India due to cultural significance, long-standing trust, and its demonstrated ability to preserve wealth across economic cycles. However, growing interest in alternative metals and the expansion of commodity-based financial products make it essential to contextualize the findings of this study within the Indian investment environment. First, the results reaffirm gold's suitability as a foundational asset in Indian portfolios. Its relatively low volatility, steady long-term appreciation in INR terms, and proven resilience during global uncertainty make it highly compatible with the conservative risk preferences of many Indian households. Gold also benefits from deep liquidity through established channels such as jewelry, coins, ETFs, and sovereign gold bonds, further enhancing its accessibility and reliability.

Second, non-gold metals can offer complementary benefits when integrated thoughtfully into diversified portfolios. Silver, for instance, provides exposure to both investment-driven demand and high-growth industrial use cases such as solar photovoltaic manufacturing and electronics. Its moderate risk level compared with other non-gold metals makes it an appealing secondary asset for investors seeking higher returns without taking extreme speculative positions. Platinum also aligns well with the conservative profile of Indian investors, offering diversification within the precious metals category with relatively controlled risk.

Third, copper provides Indian investors with a direct avenue for participating in global industrial and infrastructural growth cycles. While copper's volatility is higher than that of gold or platinum, its strong link to long-term structural trends—urbanization, renewable energy expansion, electric mobility infrastructure—makes it attractive for investors with medium risk tolerance and multi-year investment horizons. Copper's behaviour in Indian rupee terms further reflects both global demand cycles and domestic currency movements, making it relevant for strategic allocations.

Fourth, palladium and lithium, despite their high return potential in select years, exhibit extreme volatility and large downside risks. Indian investors, who generally prioritize capital preservation, may find these metals appropriate only for small tactical allocations or thematic investments through professionally managed vehicles. Their suitability is greatest for high-risk investors seeking to benefit from technological transitions such as EV adoption or changes in emission standards. For most retail investors, however, the severe fluctuations observed in both metals present substantial portfolio risk.

The study highlights the benefits of a multi-metal strategy that integrates gold with carefully selected non-gold metals according to investor objectives. Conservative investors may emphasize gold, silver, and platinum, using copper sparingly for growth exposure. Moderate-risk investors can increase copper allocation and incorporate small shares of lithium or palladium under professional guidance. High-risk investors may tactically use palladium or lithium to enhance returns during favourable market cycles.

The findings underscore that while gold remains the cornerstone of Indian metal investments, diversified exposure to non-gold metals—when aligned with risk tolerance and economic outlook—can enhance portfolio performance and resilience. These implications support a more informed investment approach in an evolving commodity landscape increasingly influenced by technology, sustainability, and global supply-chain trends.

6 CONCLUSIONS

This study conducted a comprehensive comparative evaluation of five non-gold metals—silver, platinum, palladium, copper, and lithium—against the benchmark performance of Gold, using annual INR-per-gram prices spanning a ten-year period from 2015 to 2024. By analyzing long-term price trends, annual returns, volatility, downside deviation, and Value-at-Risk, the study provides a multi-dimensional understanding of the investment characteristics of these metals within the Indian context. The results demonstrate that each metal exhibits a distinct risk–return profile shaped by its industrial application, supply dynamics, and global economic influences. Silver displayed hybrid behavior due to its dual industrial and investment demand, showing moderate volatility and episodes of strong appreciation. Platinum exhibited stable price movements, reflecting its recycling-driven supply base and steady industrial utilization. Copper behaved as a growth-linked industrial metal, offering substantial returns during expansionary cycles but also showing sensitivity to global slowdowns. Palladium and lithium showed extreme fluctuations, driven by supply constraints, regulatory transitions, and rapid technological changes. These metals provided exceptional returns in certain periods but also posed significant downside risks, making them suitable primarily for high-risk or thematic investment strategies.

Gold's performance over the decade reaffirmed its long-standing reputation as a low-volatility, crisis-resilient asset. Its steady appreciation in INR terms and controlled downside risk underscore why it remains a central component of Indian investment portfolios. Compared with gold, the non-gold metals offered higher potential returns in select years but at the cost of substantially higher risk exposure. This contrast highlights the importance of aligning metal selection with investor objectives, risk tolerance, and time horizon. The comparative framework developed in this paper provides valuable insights for metal-based portfolio construction. Investors seeking long-term stability may emphasize gold, silver, and platinum, while those pursuing growth-oriented strategies may incorporate copper. High-risk investors may consider limited exposure to palladium or lithium during favourable market conditions. The findings also emphasize the importance of diversification, as no single metal consistently outperformed across all metrics.

This study contributes to the limited body of literature analyzing non-gold metals from an Indian perspective using rupee-denominated data. By integrating price trends, risk metrics, and portfolio-oriented interpretation, the study offers a practical guide for investors and analysts evaluating the role of non-gold metals in diversified portfolios. Future work may extend the analysis using higher-frequency (monthly or daily) data, incorporate econometric forecasting models, or examine dynamic portfolio optimization techniques involving multiple metals and macroeconomic variables.

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ETHICS STATEMENT

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

STATEMENT OF CONFLICT OF INTERESTS

The authors declare that they have no conflicts of interest related to this study.

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