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EVALUATING WHEAT HEDGING EFFICIENCY USING PRECIOUS METALS: A PORTFOLIO ANALYSIS FROM VOJVODINA

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Abstract: *This study analyzes the effectiveness of hedging wheat in Vojvodina, Serbia, using gold and silver to reduce portfolio risk and stabilize returns. Wheat is a key regional commodity, highly sensitive to global price fluctuations and local market conditions. Daily CBOT wheat futures and historical gold and silver prices from 2019–2024 are used to calculate log returns. Minimum-variance portfolios are constructed following the Markowitz framework. Hedging efficiency is measured with the Hedge Effectiveness Index (HEI) and risk-adjusted performance with the Sharpe ratio. Results show that hedging with gold provides the highest risk reduction (HEI 94.38%, Sharpe 0.2025), while silver offers moderate protection (HEI 87.40%, Sharpe 0.0456). These findings demonstrate that precious metals effectively stabilize wheat portfolios and improve the risk–return trade-off. The study highlights practical implications for producers and investors in Vojvodina, enabling portfolio protection against price volatility. Future research could extend the analysis to other Western Balkan countries, additional commodities, and futures contracts.*

Keywords: *wheat, Vojvodina, hedging, precious metals, portfolio risk*

JEL Classification: *G11; G13; Q11; Q14*

INTRODUCTION

Wheat is one of the most important cereals globally, ranking immediately after maize in terms of production volume. In the economies of the Western Balkans, agriculture plays a crucial role, with Serbia leading in wheat production, and Vojvodina accounting for more than 70% of the national output. A similar situation is observed in Bosnia and Herzegovina, where wheat self-sufficiency stands at approximately 54%,

with notable territorial disparities.

Crises such as the COVID-19 pandemic, the Russia–Ukraine war, and challenges related to sustainable development have highlighted the need to strengthen local food production to enhance the resilience of food systems. Research indicates that Western Balkan countries generally have lower self-sufficiency in cereals and weaker competitiveness compared to most European nations, with factors such as GDP per capita, political stability, and agricultural productivity significantly influencing these outcomes.

In this context, the wheat market in Vojvodina has faced pronounced price fluctuations in recent years. Global supply chain disruptions and rising world wheat prices directly affect domestic prices and yields, while Serbia partially imports wheat and exports a portion of its production. According to, wheat prices increased by 24.53% in March 2022, while reported a 55% increase immediately after the outbreak of the war in Ukraine. These data quantify heightened volatility and emphasize the connection between the local market and global developments.

Market mechanisms also play a role in price formation. demonstrate that storable commodities, such as wheat, have an empirically confirmed price floor, which encourages producers to delay sales to contribute to market stabilization. In such an environment, hedging strategies that combine agricultural products with more stable financial instruments, such as gold and silver, effectively reduce portfolio risk. Precious metals were selected due to their relatively low volatility, historical correlation with agricultural commodities, and status as safe assets, providing protection against market fluctuations and extreme shocks.

The aim of this study is to assess the effectiveness of hedging wheat prices in Vojvodina using precious metals. To this end, two minimum-variance portfolios were constructed – wheat–gold and wheat–silver. Hedging effectiveness is measured using the Hedge Effectiveness Index (HEI), while the Sharpe ratio evaluates the risk–return profile of the portfolios. The analysis is based on daily wheat futures from the CBOT, which serve as a global price benchmark and reflect price movements in Vojvodina, alongside precious metal prices. The methodological framework relies on the portfolio approach, which allows optimization of the risk–return trade-off under various market conditions.

This study contributes to a better understanding of mechanisms for mitigating price risks in the wheat market, providing practical guidance for farmers, exporters, and policymakers. At the same time, it enriches the literature on commodity hedging in smaller and open economies, highlighting the role of precious metals in portfolio stabilization and the preservation of production value

Based on the research objectives and previous literature, the following hypotheses were formulated:

H1: Hedging wheat with gold significantly reduces portfolio risk in Vojvodina, as reflected in high values of the Hedge Effectiveness Index (HEI).

H2: Hedging wheat with silver reduces portfolio risk, although it is less efficient compared to gold.

H3: Combining wheat with precious metals improves the risk–return trade-off, as indicated by an increased Sharpe ratio compared to the unhedged portfolio.

The remainder of the paper first presents a review of the relevant literature,

followed by a description of the methodology. Subsequently, empirical findings are presented, and the discussion section interprets the research results. The final part of the paper is dedicated to conclusions and practical implications of the study.

LITERATURE REVIEW

This section reviews studies on hedging strategies employing precious metals across various asset classes, including agricultural commodities, equities, and other financial instruments. investigate the use of spot corn prices combined with futures of precious metals, utilizing variance (Var), value at risk (VaR), and conditional value at risk (CVaR) within a dynamic conditional correlation (DCC) framework. Their results indicate that gold represents the most efficient hedging instrument due to its low correlation with corn and reduced overall risk, with an optimal portfolio allocation of 27:73 in favor of gold. emphasize gold's role as a safe-haven asset and store of value, demonstrating its ability to stabilize portfolios during periods of market stress. further confirm the importance of precious metals in mitigating geopolitical risk (GPR), showing that gold and silver provide effective short- and medium-term protection, while platinum and palladium mainly act during severe supply shocks.

The application of these findings to European commodity markets illustrates that geopolitical events, including the war in Ukraine, significantly influence wheat and corn price volatility . employs parametric Value-at-Risk models and the Omega ratio to analyze extreme portfolio risk for cereal- and "soft"-commodity combinations, underlining the importance of diversification and advanced risk measures. demonstrate that combining agricultural commodities with precious metals, particularly gold and silver, reduces exposure to geopolitical and market risks, providing reliable protection and stabilizing returns.

Research on European equity portfolios further supports the stabilizing role of precious metals. apply GARCH models and Markowitz mean-variance optimization, showing that gold consistently delivers stable returns, the highest Sharpe ratios, and protection against losses, while silver contributes to diversification with higher volatility. utilize TVP-VAR and multi-asset portfolio optimization, revealing that dynamic portfolios including agricultural commodities often outperform the S&P 500, highlighting the importance of incorporating commodities into diversified strategies. illustrate that combining equities with precious metals enhances the risk–return profile, with gold functioning as a key stabilizer and the application of minimum variance and HEI indices further improving protection against market fluctuations.

For the analysis of the wheat market in Vojvodina, international CBOT futures were employed as reliable and liquid reference prices, accurately reflecting global market movements . The use of these data enables precise assessment of volatility and hedging efficiency, confirming the methodological appropriateness of using futures in the regional context. The findings emphasize the significance of gold and silver as instruments for mitigating price risk, providing practical guidance for stabilizing the returns of agricultural portfolios in Vojvodina.

The wheat market in Vojvodina during 2019–2024 experienced moderate price fluctuations reflecting both global and local shocks, including the COVID-19 pandemic and the war in Ukraine. In 2022, total traded volume reached 156,719 tons, including government purchases of 82,875 tons for strategic reserves, with a peak price of

44.00 RSD/kg for the 2021 crop in May . Between March and April 2024, prices ranged from 23.20 to 23.50 RSD/kg, with a weighted average of 23.29 RSD/kg (25.61 RSD/kg including VAT), reflecting moderate fluctuations and underscoring the relevance of hedging strategies to mitigate market risk. These observations confirm that local wheat prices in Vojvodina are sensitive to global disruptions, supporting the implementation of risk management tools such as portfolios incorporating precious metals.

METHODOLOGY

The methodology of this study uses logarithmic returns to measure daily price changes of wheat, gold, and silver. Minimum variance portfolios, along with the Hedging Effectiveness Index (HEI) and Sharpe ratio, are applied to evaluate risk reduction and risk-adjusted returns for hedged wheat portfolios.

Daily logarithmic returns of wheat were calculated based on futures prices, whereas for the precious metals, gold and silver, their daily spot prices were employed. The returns were computed according to the following formula:

$$r_t = \ln \frac{P_t}{P_{t-1}} \quad (1)$$

Here P_t denotes the asset price on day t . This approach allows for a precise assessment of volatility and the interdependence between wheat and precious metal prices, forming the basis for constructing minimum-variance portfolios.

For the construction of bivariate wheat–gold and wheat–silver portfolios, the principles of Markowitz’s portfolio theory were applied, using the formula of to determine the optimal weights of the hedging asset:

$$W_s = \frac{\sigma_p^2 - \text{COV}_{p,s}}{\sigma_p^2 + \sigma_s^2 + 2 \cdot \text{COV}_{p,s}} \quad (2)$$

$$W_p = 1 - W_s \quad (3)$$

Where:

W_s – the weight of the secondary asset (s) in the two-asset portfolio,

W_p – the weight of the primary asset (p),

σ_p^2 – the variance of the primary asset,

σ_s^2 – the variance of the secondary asset,

COV_{ps} – the covariance between the two assets.

Based on the covariance and return volatilities, the weights that minimize the overall portfolio risk are calculated, achieving an efficient and time-adjusted allocation of capital.

Hedging effectiveness is quantified using the Hedge Effectiveness Index (HEI), which measures the contribution of the secondary asset in reducing portfolio risk. The HEI is calculated as:

$$HEI = \frac{\sigma_{\text{nehedžirana}}^2 - \sigma_{\text{hedžirana}}^2}{\sigma_{\text{nehedžirana}}^2} \quad (4)$$

The index compares the variance of an unhedged portfolio with that of a hedged portfolio (investment in both primary and secondary assets). HEI values close to 1 indicate effective hedging, values near zero suggest minimal impact, and negative values imply that hedging may increase risk. This approach quantifies risk reduction while acknowledging that risk can never be fully eliminated, a core principle of modern hedging theory.

Finally, portfolio performance is assessed using the Sharpe ratio. While HEI captures hedging efficiency, the Sharpe ratio evaluates the risk–return trade-off, measuring the additional return per unit of risk and enabling performance comparison across portfolios. Mathematically, it is expressed as:

$$\text{Sharpe ratio} = \frac{r_p - r_f}{\sigma_p} \quad (5)$$

Where:

r_p – portfolio return,

r_f – risk-free rate, and

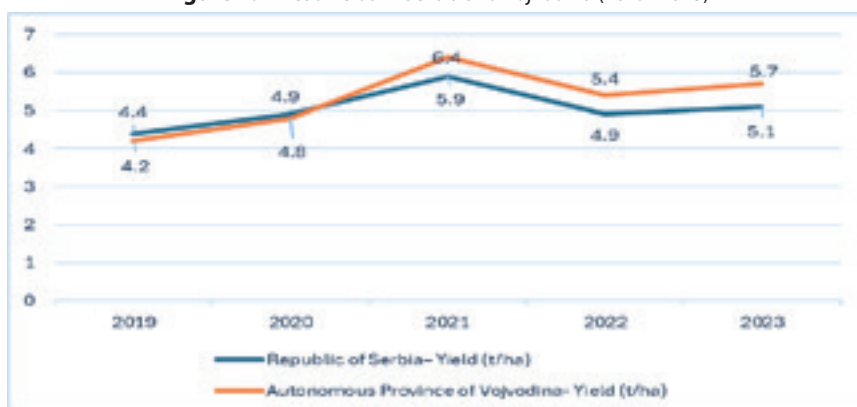
σ_p – portfolio standard deviation.

As one of the most relevant and widely used measures of investment performance in contemporary academic literature and practice, it serves as a key tool for evaluating portfolio efficiency under conditions of market volatility.

RESULTS AND DISCUSSION

The aim of this analysis is to evaluate the effectiveness of hedging wheat prices in Vojvodina using precious metals, gold and silver. Bivariate minimum variance portfolios were constructed combining wheat with each metal. The analysis is based on daily CBOT wheat futures (ZW.F) and daily spot prices of gold and silver, retrieved from the Stooq platform. The data cover the period from January 2019 to April 2024, including the COVID-19 pandemic and the war in Ukraine. Figure 1 shows wheat yields in Serbia and Vojvodina, emphasizing the importance of Vojvodina in total production.

Figure 1. Wheat Yields in Serbia and Vojvodina (2019–2023)



Source: Compiled by the author using RZZS data

Figure 1 illustrates the average wheat yields (t/ha) in the Republic of Serbia and the Autonomous Province of Vojvodina for the period 2019–2023. The data show that Vojvodina consistently achieves slightly higher yields than the national average, highlighting its significant regional role in wheat production. In 2019–2020, the difference in yields between Vojvodina and Serbia was minimal (2019 – 4.2 t/ha in Vojvodina vs. 4.4 t/ha in Serbia; 2020 – 4.8 t/ha in Vojvodina vs. 4.9 t/ha in Serbia). The year 2021 recorded the highest yield increase for both regions, with Vojvodina reaching 6.4 t/ha and Serbia 5.9 t/ha, reflecting favorable agro-economic conditions. After 2021, yields slightly declined and stabilized: in 2022, Vojvodina reached 5.4 t/ha and Serbia 4.9 t/ha, while in 2023 there was a modest increase (Vojvodina – 5.7 t/ha; Serbia – 5.1 t/ha). Data for 2024 are not yet available, which is why the analysis is presented up to 2023.

The increased stability and relatively high average wheat yields in Vojvodina suggest that this region may be suitable for implementing hedging strategies, which will be further examined through the calculated indicators of minimum variance portfolios, HEI index, and Sharpe ratio.

Descriptive Statistics of Individual Assets

Table 1. Descriptive statistics of returns for wheat, gold, and silver over the period from January, 2019, to April, 2024.

Assets	Mean	Variance	Skewness	Kurtosis
Wheat	0,00801	0,93645	0,66222	5,24861
Gold	0,01976	0,16014	-0,37791	3,22626
Silver	0,02524	0,65830	-0,52725	7,71184

Source: Author's calculations based on data retrieved from www.stooq.com

Based on Table 1, silver and gold exhibit the highest mean returns, while wheat has the lowest. Wheat's average daily growth rate is near zero, indicating that despite high prices, its series experienced significant negative returns due to strong price fluctuations. Variance, as a measure of risk, is highest for wheat (0.936) and lower for precious metals (silver 0.658, gold 0.160), suggesting that these metals are suitable hedging instruments. Skewness shows negative values for gold (-0.377) and silver (-0.527), and positive for wheat (0.662), reflecting the distribution of returns around the mean. High kurtosis values (kurtosis > 3) indicate extreme daily deviations, with silver showing the highest (7.711) due to economic and geopolitical turbulence, while gold remains relatively stable (3.226), confirming its role as a safe-haven asset. These skewness and kurtosis characteristics do not affect the construction of bivariate portfolios, which rely solely on variances and covariances.

Comparison of Minimum Variance Portfolios

Tabela 2. Comparative Allocation of Portfolio Instruments (in %)

Weight	Wheat_gold	Wheat_silver
Wheat	31.00	44.91
Secondary instruments	69.00	55.09
Total	100.00	100.00

Source: Author's calculations based on data retrieved from www.stooq.com

Table 2 presents the results of the constructed bivariate portfolios aimed at minimizing wheat risk, showing wheat as the primary asset and gold and silver as secondary assets. In our analysis, precious metals account for 55.09% of silver and 69% of gold in the portfolios. It is evident that the secondary assets hold a substantially higher share than the primary asset, which is expected given their significantly lower risk. The high allocation of precious metals, particularly gold, reflects their lower volatility and safe-haven role, with their portfolio weight increasing as the risk of the primary asset rises. Our findings are consistent with in the context of equities and gold, indicating that optimal metal shares depend on market trends. During periods of rising prices, metals enhance the risk–return profile, whereas in declining markets they help reduce risk, albeit with lower returns. These results confirm that gold and silver act as effective hedging instruments in wheat portfolios, highlighting the importance of adjusting metal shares in accordance with market conditions.

Descriptive Statistics of Wheat and Constructed Portfolios

Table 3: Descriptive statistics of constructed portfolios and the wheat

Portfolio's combination	Mean	Variance	Skewness	Kurtosis
Wheat	0,00801	0,93645	0,66222	5,2486
Wheat_gold	0,01065	0,05260	-0,11725	6,20046
Wheat_silver	0,00537	0,11798	-0,09434	4,74616

Source: Author's calculations based on data retrieved from www.stooq.com

After constructing the bivariate portfolios, the next step is to evaluate their performance in terms of the first four moments. To this end, Table 3 presents the descriptive statistics of the constructed portfolios. As shown in Table 3, both portfolios exhibit substantially lower variance compared to the primary asset, as well as lower variance relative to the empirical series of the auxiliary assets. This finding confirms the effectiveness of diversification, indicating that the risk of wheat is significantly reduced through the inclusion of precious metals in the portfolio. For instance, the variance of the unhedged wheat portfolio amounts to 0.936, while it decreases to 0.117 after adding silver. An even more pronounced effect is observed in combination with gold, where the variance of the wheat–gold portfolio is only 0.052, nearly 18 times lower than that of the unhedged wheat portfolio, confirming that gold serves as a more efficient risk-hedging instrument.

Regarding the third moment, i.e., skewness, the wheat–silver portfolio exhibits more favorable characteristics, with lower negative skewness and lower kurtosis of

4.746 compared to the wheat–gold portfolio, indicating a more desirable return distribution. In addition to Table 3, which presents the portfolio characteristics, Figure 2 shows a combined view of the time series for the constructed portfolios and the primary asset. This visualization clearly illustrates the daily return dynamics over the observed period, with the portfolios exhibiting considerably lower fluctuations compared to the empirical wheat series.

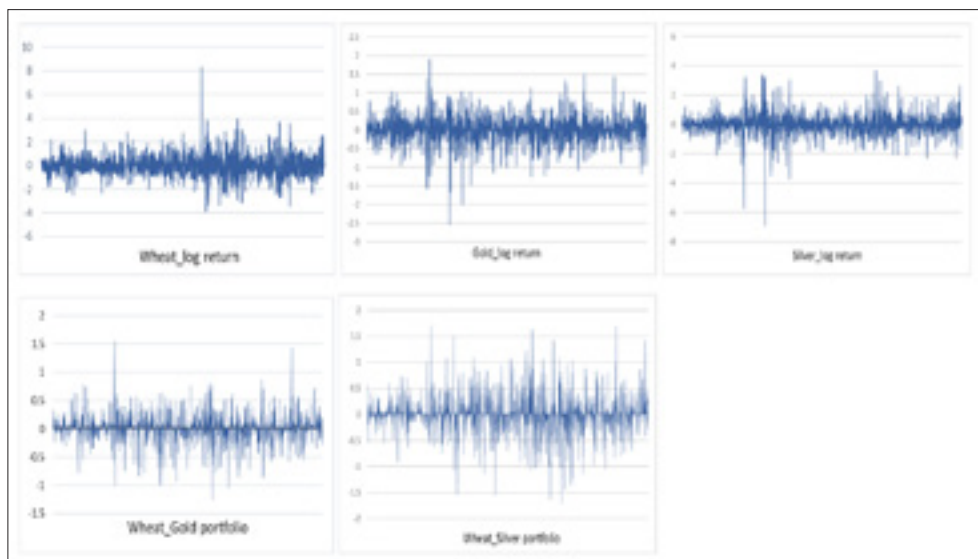


Figure 2. Comparison of Returns of Individual Assets and the Portfolio

Source: Author's calculation based on data retrieved from Stooq.com

As shown in Figure 2, during the COVID-19 pandemic, wheat returns increased by approximately +10%, followed by a decline of around –5% due to supply chain disruptions and heightened market uncertainty. In early 2022, amid the war in Ukraine, another period of volatility occurred, with a short-term price surge followed by a drop in returns of about –4%. Gold exhibited stable positive returns (up to +2% during the pandemic and around +1.5% during the war), whereas silver experienced wider fluctuations (ranging from –8% to +6%) due to its industrial exposure. In the Vojvodina market, these global shocks led to higher input costs and elevated production risks, while wheat–gold and wheat–silver portfolios, showing lower volatility (approximately –1.5% to +1.5%), confirmed the effectiveness of diversification and the hedging role of precious metals.

Performance and Hedging Efficiency Analysis

The analysis of portfolio performance and hedging efficiency, based on the Hedging Effectiveness Index (HEI) and the Sharpe ratio, highlights the role of gold and silver in stabilizing wheat portfolios from Vojvodina under conditions of heightened market uncertainty.

Table 4: HEI index values

Portfolios' combinations	HEI index
Wheat_gold	94,38%
Wheat_silver	87,40%

Source: Author's calculations based on data retrieved from www.stooq.com

Our results indicate that hedging wheat with precious metals effectively reduces exposure to price volatility. These findings support Hypothesis H1, which states that hedging wheat with gold significantly lowers portfolio risk in Vojvodina, as reflected in high values of the Hedge Effectiveness Index (HEI). As shown in Table 4, the HEI confirms this effect. The wheat–gold portfolio achieves 94.38%, while the wheat–silver portfolio reaches 87.40%, demonstrating substantial risk reduction and strong protection during crisis periods.

Table 5: Comparative overview of Sharpe ratio values

Portfolios' combinations	Sharpe ratio of wheat	Sharpe ratio of portfolios
Wheat_gold	0,0086	0,2025
Wheat_silver	0,0086	0,0456

Source: Author's calculations based on data retrieved from www.stooq.com

Building on this, our results also support Hypothesis H2, showing that hedging with silver reduces portfolio risk, although to a lesser extent than gold. Similarly, Hypothesis H3 is confirmed, as the Sharpe ratio illustrates improved risk–adjusted returns: the wheat–gold portfolio achieves a Sharpe ratio of 0.2025, whereas the wheat–silver portfolio reaches 0.0456, compared to 0.0086 for the unhedged wheat portfolio. Together, these metrics demonstrate that hedging with precious metals not only lowers absolute risk but also enhances the risk–return trade-off, offering practical protection for wheat producers and investors in Vojvodina against price fluctuations caused by global shocks, such as the COVID-19 pandemic and the war in Ukraine.

These findings are consistent with, confirming gold as the most efficient instrument for risk reduction in agricultural portfolios, and align with prior studies. show that precious metals serve as effective hedges against geopolitical risks across various commodities, while demonstrate that combining gold with the S&P 500 reduces portfolio risk and improves both HEI and Sharpe ratios. Furthermore, these results correspond with, who reported that gold improves risk-adjusted returns in bullish markets and reduces risk in bearish markets at the cost of lower returns. In our study, gold proves to be the most efficient hedging instrument for wheat, while silver provides moderate risk reduction, confirming that precious metals are effective hedging tools and that their optimal allocation depends on market conditions.

CONCLUSION

The results of this study demonstrate that hedging wheat with precious metals, particularly gold, effectively reduces portfolio risk and improves the risk–return trade-off in the Vojvodina market. Hedging with gold achieves the highest efficiency (HEI 94.38%, Sharpe 0.2025), while silver provides moderate risk reduction (HEI 87.40%,

Sharpe 0.0456), confirming Hypotheses H1–H3. These findings align with, who identifies gold as the most effective hedging instrument in agricultural portfolios, as well as with and, which highlight the protective role of precious metals against geopolitical and market risks. The results also support , showing that gold enhances risk-adjusted returns in bullish markets and reduces risk in bearish markets, whereas silver provides moderate protection. Practically, these strategies help wheat producers and investors in Vojvodina mitigate price volatility, stabilize portfolios, and increase predictability of returns, especially under conditions of heightened market uncertainty such as the COVID-19 pandemic and the war in Ukraine. This study contributes to understanding market mechanisms in Serbia's agricultural sector and confirms the effectiveness of precious metals as hedging instruments locally. Future research could extend the analysis to other Western Balkan countries, incorporate futures contracts, and include additional commodities to further optimize regional agricultural portfolios.

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