

## Equity Portfolio Optimization With Gold

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### Abstract

**Purpose:** The aim of the paper is to check if gold helps improve stock portfolio characteristics understood in the sense of the Markowitz model. If so, what are optimal shares of stocks and gold to minimize variance?

**Design/methodology/approach:** The investment portfolio optimization procedure in the Markovitz environment is made. The study is devoted to investments made by Polish investors, that is stocks are reflected by the WIG index from the Warsaw Stock Exchange. The analysis is conducted in different periods of time in 2006–2019 covering bull and bear markets of gold.

**Findings:** It is shown that gold can be used as a hedge asset; however, exact conclusions depend on the market situation. Including gold in the stock portfolio increases the portfolio rate of return and at the same time decreases risk measured with variance, however only during the bull market of gold. During the bear market, gold helps minimize risk but at the same time it lowers the portfolio rate of return compared to stocks-only portfolio. Besides, it turns out that during the bull market of gold, both skewness and kurtosis of the portfolio are more advantageous for an optimal portfolio covering both stocks and gold than for the stock one.

**Research limitations/implications:** An important assumption of the study is in what way investments in gold are made. Here, they are made by the use of spot gold prices and they are recalculated into Polish zlotys in order to check the Polish investor perspective. In reality, it is not easy to invest directly in big amounts of gold, although in the literature spot gold prices are used for such research.

**Originality/value:** The research contributes to the existing international literature on using gold in stock portfolio management by analyzing the problem from the point of view of a Polish investor.

**Originality/value:** Original work.

**Keywords:** stock portfolio optimization, gold, stocks, minimum variance portfolio.

**JEL:** G1, G11

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## Optimalizacja portfela akcji za pomocą złota

### Streszczenie

**Cel:** celem artykułu jest weryfikacja, czy złoto pomaga ulepszyć parametry portfela składającego się z akcji za pomocą złota w kontekście modelu Markowitza. Jeśli tak, jakie są optymalne udziały akcji i złota pozwalające na minimalizację wariancji?

**Metodologia:** przeprowadzono optymalizację portfela inwestycyjnego w świetle teorii Markowitza. Studium jest poświęcone inwestycjom przeprowadzanym przez polskich inwestorów, co oznacza, że akcje odwierciedlane są za pomocą indeksu WIG20 z Giełdy Papierów Wartościowych w Warszawie. Analiza prowadzona jest w różnych przedziałach czasowych w okresie 2006–2019, co pozwala na objęcie nią zarówno okresów hossy, jak i bessy panującej na rynku złota.

**Wyniki:** pokazano, że złoto może być traktowane jako instrument zabezpieczający dla portfela akcji, jednakże ostateczne wyniki uzależnione są od sytuacji rynkowej. Włączenie złota do portfela akcji podnosi jego stopę zwrotu i w tym samym czasie zmniejsza ryzyko mierzone wariancją, jednakże tylko podczas, gdy na rynku złota panuje hossa. Podczas bessy złoto pomaga zminimalizować ryzyko, ale jednocześnie obniża stopę zwrotu z portfela w porównaniu z takim, który zawiera wyłącznie akcje. Poza tym okazuje się, że zarówno skośność, jak i kurtoza stóp zwrotu z portfela są bardziej atrakcyjne w przypadku portfela optymalnego zawierającego tak akcje, jak i złoto w porównaniu z wyłącznie akcyjnym.

**Ograniczenia/implikacje badawcze:** istotnym ograniczeniem badań jest przyjęcie założenia dotyczącego sposobu inwestowania w złoto. Użyto bieżących cen złota, które przeliczono na złote w celu analizy perspektywy polskiego inwestora. W rzeczywistości, mimo że istnieje ograniczenie dla bezpośrednich inwestycji w złoto o dużej wartości, w literaturze stosuje się takie podejście.

**Originalność/wartość:** badania wnoszą wkład do istniejącej literatury przedmiotu w kontekście zastosowania złota w zarządzaniu portfelem akcji poprzez analizę problemu z perspektywy polskiego inwestora.

**Słowa kluczowe:** optymalizacja portfela akcji, złoto, akcje, portfel o minimalnej wariancji.

## 1. Introduction

The possibility of using gold as a safe haven has been a subject of many studies, however conclusions are various and often contradictory, especially in developing markets. Besides, the literature mainly concentrates on confirming or rejecting the hypothesis that gold is a safe haven or a hedge and does not look for optimal shares of gold as a part of the stock portfolio. Conclusions depend on the country analyzed, method used, time period considered.

According to the data provided by the World Gold Council (2020), the 10-year average (2008–2017) of total annual demand for gold is 4282 tonnes and it is used mainly in jewelry (52%), bar and coin (27%) as well as for technology (9%). Thus, it is a special metal whose price also determines the results of investments on financial markets. Gold has been treated as a hedge asset for many decades. However, the research concerning using gold as a hedging instrument is not unequivocal. Some papers say that it can be used as a tool of portfolio diversification, some others that it cannot. This paper verifies it from the point of view of the Polish stock investor.

The purpose of the paper is to check if gold helps improve stock portfolio characteristics understood in the sense of the Markovitz model (Markovitz, 1952). The research question is if it is possible to improve stocks rate of return and at the same time lower the value of risk measured by variance by including gold in the stock portfolio. If so, what are optimal shares of stocks and gold and how it changes the third and fourth central moment of the distribution for the optimized gold-stock portfolio compared with the stock portfolio. The author of this paper optimizes the stock-gold portfolio according to the Markovitz methodology applied, for example, by Theron and Vuuren (2018) or Soja (2019) and stocks are reflected by the WIG index from the Warsaw Stock Exchange. WIG summarizes the situation on the whole Exchange and is a total return index, so it also comprises other returns than those deriving from price changes. The research contributes to the existing literature on using gold in portfolio management by analyzing the problem from the point of view of a Polish investor investing in stocks on the domestic market. The existing literature does not treat stock-gold optimization from the point of view of a Polish investor as it associates such optimization with the gold market trend, contrary to this paper.

## 2. Literature Overview

The literature on possibilities of gold as a diversifying tool can be divided into three main streams. One of them confirms that gold is a good hedge instrument and should be used in portfolio diversification. The second one denies that gold should be applied in portfolio diversification. The third part of the literature shows that the efficiency of gold as a safe haven may depend on different conditions such as the country analyzed as well as the length of the examined period.

Unique properties of gold were noticed a long time ago. There are plenty of scientific papers confirming that gold can be used as a diversifying asset for stock investments. Sherman (1982) analyzes gold in the context of the modern portfolio theory and emphasizes that gold is less volatile than bonds or stocks and that in the majority of examined cases it reduces the portfolio volatility. Baur and Lucey (2010) prove that gold can play the role of safe haven for stocks in the US, the UK and Germany. The effect is extremely strong after extreme shocks on the market. Beckmann et al. (2015) extend the analysis conducted by Baur and Lucy (2010) by adding a new research method and study the period of 1970–2012 on a monthly basis for both developed countries and emerging economies and find out that gold generally can be considered a hedge asset, however its potential as that depends on the specific economic setting. WGC (2001) examines the role of gold as a strategic asset in the eurozone during economic uncertainty and proves that it can protect investors' portfolios and reduce

risks of different kinds of assets including stocks. Similar conclusions are drawn by Arouri et al. (2015), who use the VAR-GARCH model and some other models from the group of GARCH for comparison for the data from 2004 to 2011 and find out that gold can be a good diversification tool for stock markets as well as that past gold volatility changes play an important role in explaining conditional volatility and rates of return on Chinese stocks. It means that they should be observed when forecasting the stock market behavior. McCown and Zimmermann (2006) show with an example of the US market that gold is a zero beta asset, which in turn creates the possibility to treat it as part of a diversified portfolio. Hillier et al. (2006) show that gold has a low correlation with stock index returns, so it can be used in portfolio diversification. Chkili (2016) analyzes the link between gold and stock markets in BRICS countries using asymmetric DCC model for weekly data. The final findings are that gold increases the risk-adjusted return profile, so it can act as a safe haven during severe market conditions. Azar (2016) analyzes the possibilities of diversification with gold for different types of assets (oil, euro and deposits in Lebanese pounds), including stocks (DJIA index) from the Lebanese perspective and summarizes that benefits of including gold in a portfolio are big. Wen and Cheng (2018) question whether gold or the American dollar can be a safe haven for emerging economies. The authors calculate the low-high tail dependence between markets using copula functions and conclude that both of them can be such assets; however, the US dollar gives better results. Soja (2019) conducts examinations for the eurozone indexes and seeks optimal shares of gold against stocks and bonds in 2007–2017 using a structural vector auto-regression model. The paper concludes that the optimal portfolio should include 1% to 9% of gold depending on the investor's attitude to risk. Bekiros et al. (2017) confirm that gold is both a hedge and a safe haven for emerging economies (BRICS) and consider the drawn conclusions important in building diversified portfolios. Ciner et al. (2013) check relations between rates of return for different asset classes (also gold) for the US and the UK applying conditional correlations and their fluctuations in time as well as quantile regressions. They show that gold has always been a safe haven. For example, it was a hedge during the last financial crisis in America, as well as in the earlier time in 1990. Flavin et al. (2014) check if gold can be a safe haven for equity portfolio managers and show that it reduces risk when markets go down. Fernando (2017) points out that many investors choose gold because they treat it as a safe asset. What is more, the author shows that in 1999–2012 it let generate higher rates of return than US shares. Such conclusions surely suggest that gold can be at least a part of a diversified portfolio. Liu et al. (2016) investigate the role of gold as a safe haven in extreme economic conditions and during a normal situation in 2000–2013 in 7 developed countries such as: the UK, Germany, Switzerland, the USA, Canada, Japan, Australia.

They come to the conclusion that for the majority of countries gold can be treated as a safe haven when stock markets diminish. The authors also show the existence of skewness of rates of return on gold. Mensi et al. (2015) point out that global investors can take advantage of gold as a risk diversification asset reducing the downside risk in 6 GCC oil-based stock markets. Lucey et al. (2019) show that gold is negatively correlated with equities and suggest that it should be used as a diversification mean. Pullen et al. (2014) also suggest that gold can be used as a diversifying tool; they, however, point out that it is important to choose the right instrument which is used to invest in gold. Gold bullion seems to have the best diversification capacity out of gold stocks, gold mutual funds or gold ETFs. Lean et al. (2015) analyze French portfolios from 1949 to 2012 and prove that stock portfolios with gold dominate stochastically those without gold and advise this precious metal for risk averse investors. What is more, this result is even stronger during a crisis time.

Although the majority of papers suggest that gold can be a safe haven, some also show contrary conclusions meaning that gold cannot be a hedge asset or if so, a very weak one. In this stream of the literature, one should mention Ghazali et al. (2013), who use an econometric model to examine the role of gold in developing countries in 2001–2013 with an example of Malaysia. When a market shock appears, gold rates of return go in the same direction as stock market returns. Therefore, they conclude that it plays a minor role as a diversifying instrument on the market and that at best it can be used as a weak safe haven for stockholders during a financial crisis. Conclusions which do not confirm that gold is a hedge asset are also depicted by Lucey and Li (2014), who examine properties of 4 precious metals (gold, silver, platinum, palladium) from the point of view of the American market and reveal that although silver, platinum and palladium can play a role of a safe haven, gold cannot. Rohaya et al. (2018) take the example of Malaysia and examine gold as a hedge for portfolios of stocks, bonds and various currency rates in 2001–2017, dividing this time into shorter time periods depending on the existence or non-existence of a crisis situation. They find out that gold is a weak hedge for stocks. Ratner and Klein (2008) test the use of gold as an investment asset. On the basis of equity returns from 1975 to 2005, they summarize that although gold has a low correlation with US stocks, the conducted optimization shows that long-run advantages of including gold in the equity portfolio are not that high.

The third group of papers show that gold can be treated as a hedge asset only for some countries or for short-time hedge or that it depends on the method used. Here one must point out Baur and Dermott (2010), who test the hypothesis that gold is a safe haven for stocks for major emerging and developing countries in 1979–2009. They summarize that it is confirmed for major European stock markets, as well as for the American

ones, however not for Australia, Canada, Japan and large emerging markets such as BRICS countries. In turn, Bredin et al. (2015) conclude that gold can be a short-time hedge, whereas in the long run it can increase the downside risk if used for stocks or debt portfolios. Theron and Vuuren (2018) apply the Markowitz model and construct 3 different portfolios with assets selected from developing economies and compare their performance in the Markowitz environment. One is Most Diversified portfolio, another Minimum Variance portfolio, the third one is an Equally-Weighted portfolio and the last one is a Maximum Sharpe portfolio. The authors use market index data from developing countries. They conclude that although in previous studies Most Diversified portfolios seemed to show better results understood as better diversification and a higher Sharpe ratio than other strategies in the case of developed markets, it could not be confirmed. The portfolio which outperformed others in the examined period 2008–2016 was the Maximum Sharpe portfolio. The lowest returns were generated by the Minimum Variance portfolio. Bulut and Rizvanoglu (2019) check the role of gold as a safe haven for 24 emerging and developing countries in 2000–2018 using the GARCH-copula approach. For some countries, gold turns out not to be a safe haven, for others a weak safe haven and only for 6 countries a strong haven.

All in all, the majority of scientific papers prove that gold can be treated as a safe haven (at least a weak one) and used in portfolio diversification. Sometimes they emphasize that the potential of gold in this role depends on different economic conditions and the research method used. In their analysis, authors apply different mathematical and statistical tools starting from the Markowitz model, ending with copula functions.

### 3. The Scope of the Research

The aim of the research is to check if gold helps improve portfolio characteristics understood in the sense of the Markowitz model (Markowitz, 1952). The research question is if it is possible to improve the stock rate of return and at the same time lower the value of risk measured by variance by including gold in the stock portfolio. If so, what are optimal shares of gold and stocks to minimize variance and improve the stock rate of return? If the answer to the research question is yes, it would mean that a 100% stock portfolio is not an efficient portfolio from the point of view of the Markowitz efficient frontier.

The author checks if gold can be used as a diversifying asset for the stock portfolio which is built with the example of the WIG index from the Warsaw Stock Exchange. Daily data were used as in Pullen et al. (2014). Logarithmic rates of return were used for portfolio optimization. They were calculated with the use of close prices. Data were taken from the internet

page [www.stooq.com](http://www.stooq.com) and the internet page of the World Gold Council. Average daily rates of return were calculated as in Choudhry (2001, p. 34). Portfolio optimization for the minimal variance was conducted according to formulas for portfolio rate of return and portfolio variance in Markowitz (1952). The portfolio of two risky assets (gold and stocks) was made as also shown in Bodie et al. (2002, pp. 208–217). The conducted study assumes that an investor does not use short sale. This means that the optimization problem is:

$$V \rightarrow \min$$

By changing values of:

$$\omega_1, \omega_2$$

Under the following imposed constraints:

$$\omega_1 + \omega_2 = 1$$

$$\omega_1, \omega_2 \geq 0$$

$$r_{p,t} \geq 0$$

Where:

V – stock and gold portfolio variance understood as in the context of the Markowitz portfolio theory

$\omega_1, \omega_2$  – shares of stocks and gold

$r_{p,t}$  – portfolio rate of return

After having found portfolios optimized with variance, the author checks if they also assure better or at least the same values of skewness and kurtosis compared to stocks portfolios.

As stocks, the WIG from the Warsaw Stock Exchange was used and gold investments are conducted according to gold spot prices published by the World Gold Council. Gold prices given by this institution are in American dollars and they were recalculated into Polish zlotys according to the USD/PLN currency rate. Such an approach means that an investor does not bear the additional currency rate risk but it is built into the optimal portfolio created. Possibilities of using gold as a diversifying asset were analyzed during 2006–2019, however the time span was not only analyzed as a whole, but also divided into different periods of time depending on the gold market situation (bull market or bear market). The data were sorted and divided into the following research subperiods:

- The period 2006–September 2011 – the time comprising the gold bull market. The assumption is that an investor constructs a portfolio at the



beginning of 2006 in order to take advantage of predicted rising prices of gold,

- The period October 2011 – 2015 to cover the period when the gold bear market appeared. Similarly to the previous time span, the assumption is that an investor constructs a portfolio at the beginning of this period,
- The period 2016 – 2019 as the gold bull market,
- The whole analyzed period 2006–2019 which covers different behavior of the gold market.

#### 4. The Presentation of Research Results

Table 1 and Table 2 show summary statistics for the WIG index and gold. All measures for both assets fluctuate in different time periods. The average daily rate of return for the WIG index is positive for all periods, whereas for gold it is only negative for the period October 2011 – 2015. What is more, in all periods of time variances for WIG are lower than variances for gold. It means that from the point of view of risk in the Markowitz theory, stocks from the WIG index are a better investment than gold. Besides, kurtoses for all cases are worse for gold than for WIG. However, an investor with high risk-tolerance may think about using gold in portfolio diversification if it turns out that it has a low correlation with stocks, because in the majority of periods the average rate of return is higher for it than for the WIG index. Besides, skewness is always negative for WIG whereas for gold it is negative for one period only (bear market).

2006–2019				
	Percentiles [%]	Smallest [%]	Mean [%]	0.0135147
5%	-1.870396	-6.88133	Standard deviation [%]	1.205558
50%	0.0422038	Largest [%]	Variance	1.453371
95%	1.856392	6.020564	Skewness	-0.4642541
99%	3.088401	6.083444	Kurtosis	7.03448
2006–September 2011				
	Percentiles [%]	Smallest [%]	Mean [%]	0.0041427
5%	-2.584059	-6.88133	Standard deviation [%]	1.522464
50%	0.0528544	Largest [%]	Variance	2.317897
95%	2.282224	6.020564	Skewness	-0.4352255
99%	4.038664	6.083444	Kurtosis	5.662862



Table cont.

October 2011–2015				
	Percentiles [%]	Smallest [%]	Mean [%]	0.0183475
5%	-1.538082	-5.354393	Standard deviation [%]	0.955123
50%	0.0395865	Largest [%]	Variance	0.9122599
95%	1.513017	3.089319	Skewness	-0.4621266
99%	2.422789	3.990261	Kurtosis	6.273054
2016–2019				
	Percentiles [%]	Smallest [%]	Mean [%]	0.0219686
5%	-1.473034	-3.393485	Standard deviation [%]	0.8815421
50%	0.0307557	Largest [%]	Variance	0.7771164
95%	1.473852	2.733354	Skewness	-0.2096015
99%	2.169903	3.005228	Kurtosis	4.146578

Tab. 1. Summary statistics for the WIG index in the examined periods. Source: Own calculations.

2006–2019				
	Percentiles [%]	Smallest [%]	Mean [%]	0.0352724
5%	-1.848934	-8.875427	Standard deviation [%]	1.26313
50%	0.010394	Largest [%]	Variance	1.595496
95%	2.014877	9.594247	Skewness	0.141802
99%	3.835671	9.984409	Kurtosis	9.076984
2006–September 2011				
	Percentiles [%]	Smallest [%]	Mean [%]	0.0800456
5%	-2.309584	-6.988416	Standard deviation [%]	1.540041
50%	0.0566906	Largest [%]	Variance	2.371726
95%	2.4695	6.906813	Skewness	0.0214468
99%	4.413584	9.984409	Kurtosis	6.701925
October 2011–2015				
	Percentiles [%]	Smallest [%]	Mean [%]	-0.0239657
5%	-1.874631	-4.37205	Standard deviation [%]	1.141348
50%	-0.0036583	Largest [%]	Variance	1.302675
95%	1.767511	4.575614	Skewness	-0.2598588
99%	3.302987	5.472663	Kurtosis	8.618731

Table cont.

2016–2019				
	Percentiles [%]	Smallest [%]	Mean [%]	0.0332858
5%	-1.310341	-2.444684	Standard deviation [%]	0.8817015
50%	-0.0134436	Largest [%]	Variance	0.7773975
95%	1.322107	4.286748	Skewness	1.590391
99%	2.491578	9.594247	Kurtosis	17.97014

Tab. 2. Summary statistics for gold in the examined periods. Source: Own calculations.

Data depicted in Table 3 show that gold and rates of return on the WIG index have a low correlation which lets us assume that gold can be used as a stock portfolio diversifying asset in a Markowitz portfolio.

	2006–2019	2006–September 2011	October 2011–2015	2016–2019
Pearson correlation coefficients	-0.1704	-0.1830	-0.0901	-0.2372
Covariance	-0.2595	-0.4290	-0.0983	-0.1843

Tab. 3. Relations between rates of return on the WIG index and gold. Source: Own calculations.

Portfolio optimization, whose results are shown in Table 4, is conducted under the assumption that an investor wants to make the WIG rate of return the same or higher and at the same time to minimize risk measured with variance. Thus, the author assumes that an investor wants to achieve a non-negative rate of return and at the same time to have as low risk measured with variance as possible. Optimizing lets us look for the best shares of gold and stocks in the portfolio.

	2006–2019	2006–September 2011	October 2011–2015	2016–2019
Gold share [%]	47	49	40	50
Stocks share [%]	53	51	60	50
Stocks average daily rate of return [%]	0.04	0.00	0.02	0.02
Gold average daily rate of return [%]	0.01	0.08	-0.02	0.03
Assumed portfolio rate of return [%]	$\geq 0$	$\geq 0$	$\geq 0$	$\geq 0$

Table cont.

	2006–2019	2006–September 2011	October 2011–2015	2016–2019
Portfolio rate of return [%]	0.02	0.04	0.00	0.03
Gold variance	1.60	2.37	1.30	0.78
WIG variance	1.45	2.32	0.91	0.78
Portfolio variance	0.84	1.37	0.59	0.35

Tab. 4. Results of portfolio optimization for the WIG index and gold. Source: Own calculations.

The results depicted in Table 4 show that during the gold bull market (2006–September 2011 and 2016–2019) it is possible to adjust gold and stocks shares in such a way that the optimal portfolio rate of return is higher than for the stock portfolio and at the same time its variance is lower. This in turn means that a portfolio built of stocks only during the gold bull market is not an efficient portfolio understood in the sense of the Markowitz theory. In all periods, the WIG index generates a non-negative average rate of return, whereas gold generates positive rates of return except for the time period: October 2011–2015. The main assumption is to make – thanks to the use of gold – the average daily rate of return on stocks the same or higher than for a 100% stock portfolio, which is not possible for the gold bear market as well as for the long period of time comprising both bear and bull markets.

For the period 2006–2019, the achieved portfolio rate of return is lower than the one generated for stocks only, however variance is only 0.84 compared to 1.45 for WIG and 1.60 for gold. For the period 2006–September 2011, the portfolio variance 1.37 is also much lower than both gold variance 2.37 and WIG variance 2.32 whereas the portfolio rate of return is 0.04, which is a higher value than for having stocks only in a portfolio. For the time October 2011–2015, the optimization procedure gives the result of 0.59 variance, which is lower than 0.91 for WIG20 and 1.30 for gold, however it gives a lower return. In 2016–2019, portfolio variance 0.35 is lower than gold variance 0.78 and WIG variance 0.78 while the portfolio rate of return is higher than on stocks. As far as gold shares are concerned, optimal portfolios are different for various examined periods and they are the following: for 2006–2019 the optimal amount of gold for risk minimizing is 47%, for 2006–September 2011 it is 49%, for October 2011–2015 it is 40% and for 2016–2019 the optimal amount of gold is 50%. To sum up, in all cases, the optimal amount of gold is equal to or lower than half of the portfolio. Besides, optimal portfolios for gold bull markets will mean both minimizing risk and increasing the stock rate of return whereas optimal portfolios for the bear market or the period with different gold fluctuations will only mean risk minimizing at the cost of a lower rate of return. Thus, during bear markets, the share of gold should be chosen by risk-averse investors.

The next step of the research is to check whether the optimal portfolio built in the Markowitz environment that is based on the second central moment of the distribution will also have better characteristics of the third central moment (skewness) and fourth central moment (kurtosis). To check this research question, the author builds the Markowitz optimal portfolio with shares depicted in Table 4 for each period and calculates these statistics. The results are shown in Table 5.

	2006–2019	2006–September 2011	October 2011–2015	2016–2019
Skewness	-0.2733887	-0.2302746	-0.5287436	0.0564824
Kurtosis	6.080253	4.643232	6.827194	3.970022

*Tab. 5. Summary statistics for optimal portfolios built of gold and stocks in examined periods. Source: Own calculations.*

If one compares the data from Table 5 with those from Tables 1 and 2, it turns out that some Markowitz optimal portfolios have worse skewness and kurtosis than stocks portfolios. In 2006–2019, skewness for WIG is -0.46 and for gold 0.14. For the optimized portfolio, it is -0.27. Both for stocks and for the optimized portfolio, the distribution of rates of return is skewed left, however it is less skewed for the optimal portfolio. At the same time, it is skewed right for the gold portfolio. It means that from the perspective of gold investors, stocks worsen the portfolio characteristics. However, the assumption of the study is to diversify a stock portfolio not a gold portfolio, so from the point of view of this study it does not matter. As far as kurtosis is concerned, for WIG it is equal to 7.03 and it is higher than for the optimized portfolio (6.08). The same relation is true for gold (9.08). In 2006–September 2011, portfolio skewness is -0.23 whereas for the WIG index it is worse (-0.44). The same conclusion can be drawn for kurtosis which is 4.64 for the portfolio and 5.66 for stocks. Other findings refer to the period October 2011–2015, where the optimized portfolio has worse skewness (-0.53) and worse kurtosis (6.83) than stocks (-0.46 and 6.27). For 2016–2019, stocks skewness is -0.21 and kurtosis is 4.15 and for the optimized portfolio skewness is 0.06 and kurtosis is 3.97, which means that also for this period the Markowitz optimized portfolio makes both skewness and kurtosis values better for an investor.

To sum up, gold rates of return have a negative and low correlation with stock returns, so it can be used as a hedge asset, which is also shown in Lucey et al. (2019) and Hillier et al. (2006). Hillier et al. (2006) emphasize that it is true especially in severe market conditions measured with high volatility on stock markets. This study presents a different approach as it is shown that abilities of gold as a hedge asset depend on the trend on the gold market. For bull gold market periods, optimized gold-stocks portfolios assure the lowest risk possible measured with variance, at the

same time they let increase the rate of return and decrease risk measured with skewness and kurtosis. For the gold bear market, gold turned out to be a diversifying asset only from the point of view of variance minimizing, because it does not lead to an increase or at least the same value of the rate of return and simultaneously risk measured with skewness and kurtosis rises. For the whole period 2006–2019, optimization worsens the rate of return, however it decreases not only risk measured with variance, but also with skewness and kurtosis, thus risk-averse investors can use it in their portfolio. Thus, gold can be the best hedge asset during a gold bull market and lets create the Markowitz efficient portfolio. Such conclusions add up to and are consistent with Beckmann et al. (2015), who examine emerging markets and conclude that gold generally can be a hedge asset but the final effect depends on the economic setting. However, these authors consider different economic conditions depending on stock returns. One approach considers the time when stock returns are average whereas the second one studies extreme market conditions when stocks volatility is high. In this study, it is different, although conclusions are similar, the results are given according to the gold market situation. Although it is concluded that gold can help optimize a portfolio against variance during the bull gold market and at the same time lets create the Markowitz efficient portfolio, shares of gold are different for different periods of time. It is consistent with the research results shown in Lucey et al. (2019).

## 5. Conclusions, Limitations and Possibilities of Further Studies

Low and negative correlation coefficients between WIG index and gold say that gold can be used as a diversifying asset for stocks on the Warsaw Stock Exchange.

The literature conclusions concerning the application of gold in portfolio hedging are different for different countries, periods of time and various methods, often contradictory. The results of this study suggest that generally gold can be a hedge asset for a Polish stock investor, however final results depend on the trend on the gold market. During the gold bull market, it both lowers risk measured with variance, diminishes skewness and kurtosis, as well as increases the rate of return on the portfolio. It lets create an efficient portfolio in the light of the Markowitz theory. Other conclusions are drawn for the gold bear market when it helps minimizing risk only, so it can be applied by risk averse investors. This study suggests that treating gold as a hedge asset depends on the gold market trend. It is different from other studies where conclusions depend on the trend on the stock market.

An important assumption of the study is in what way investments in gold are made. Here, they are made by the use of spot gold prices and they are recalculated into Polish zlotys in order to check the Polish investor perspective. In reality, it is not easy to invest directly in gold, although in the literature spot gold prices are used for such research. Instead, it would be possible to use some derivative instruments on gold, however in such a case the so-called basis risk appears. It is understood as the possibility of different quotations of a derivative against a spot market. If an investor uses derivatives instead of buying gold directly, it may create a certain difference in results. Another limitation of the study is that gold-stock shares are not universal for different periods of time and the hedge function of gold depends on the trend on the gold market. It requires a sophisticated knowledge from investors to analyze what trend is expected on the gold market. It would also require changes of shares of gold and stocks depending on the gold market trend as well as the period of time. This would generate additional transaction costs. Generally, shares which are optimal in one historical period do not have to turn out optimal in the next period.

The subject deserves further studies concerning for instance the optimization of skewness or kurtosis. It could be also interesting to optimize other more advanced risk measures like lower partial moments measures or maximum drawdown measures. Another direction of further studies is the examination of possibilities of using gold by Polish investors not only in stocks, but also in bonds. Besides, other risk measures can be used to compare stock, gold and optimal portfolio characteristics. What is more, other methods of optimization could be used. Another challenge could be checking what period of time is needed in order to achieve advantages from the bull market. In other words, what share of the bull and bear market is possible to treat gold as a hedge asset which lets build the Markowitz efficient portfolio. In this study, bull and bear markets existed for 100% of the research period.

All in all, the research contributes to the existing international literature on using gold in portfolio management by analyzing the problem from the point of view of a Polish investor investing in stocks on the domestic market. Besides, it presents optimal shares of gold in the portfolio for such investors. It also shows possibilities of gold as a hedge asset during different trends on the gold market and not according to trends on the stock market as in the existing literature. It proves that properties of gold as a hedge asset depend on the situation on the gold market. The findings are definitely useful for investors.

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