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Gold market and selected Nordic stock markets: Granger causality

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Abstract

Motivation: The turbulence in financial markets, especially stocks, makes investors seek safer ways of capital allocation. Gold exhibiting a low or negative correlation with stocks can constitute an alternative form of investment for them. The price volatility of aforementioned assets has impact on investors' decisions. That is why the assessment of interrelations between stock and gold returns is important. The direction of causality between the analysed variables is reflected by the fact that investors tend to transfer their funds from gold markets to more profitable markets, or return to gold markets. The research focuses on linkages between gold-stock markets of selected Nordic countries which in comparison with countries classified as key producers and consumers of gold were not under investigation so far. There is therefore a research gap in empirical research.

Aim: The aim of this paper is to investigate the causal relationship between the rates of return on stock markets in three Nordic countries, represented by their respective indices — OMXH25 (Finland: the Helsinki Stock Exchange Index), OMXS30 (Sweden: the Stockholm Stock Exchange Index) and OSEAX (Norway: the Oslo Børs All Share Index) — and the returns from investment in gold. The VAR model was applied in the analysis to perform a Granger non-causality linear test, along with decomposition of variance and the impulse response function. The study covered the period between September 2001 and October 2020.

Results: The study showed no causality between the analysed rates of return, except in Norway, where the gold market was found to have an impact on the stock market, assuming a statistical significance of 0.14. In the other two countries, changes in gold prices did not affect stock prices, and vice versa.

Keywords: Nordic stock markets; domestic gold price; Granger causality; VAR models
JEL: G11; G15; C32

1. Introduction

Stock markets can constitute an alternative form of capital investment to investments in gold, since gold demonstrates a low or negative correlation with stocks. Low rates of return, and in particular collapsing stock markets, compel investors to return to gold, considered a relatively safe investment, whereas rising stock prices weaken investors' interest in this precious metal. Therefore, it is important to investigate the impact of these stock markets on the gold market (prices), and vice versa, including their interrelations. Investors' decisions to allocate their capital on the aforementioned markets determine the type and direction of causality of these assets.

The aim of this paper is to evaluate the causal relationship between the rates of return on investments in gold, and the rates of return on the stock markets in three Nordic countries, Finland, Sweden and Norway, represented by the following stock exchange indices: the OMX Helsinki 25 Index (OMXH25), the OMX Stockholm 30 Index (OMXS30) and the Oslo Børs All Share Index (OSEAX), respectively. These countries in comparison with countries classified as key producers and consumers of gold were not under investigation so far. There is therefore a research gap in empirical research. The share of the analysed countries in world's gold production has been around 0.5% in recent years. Moreover, their gold reserves, treated as strategic assets, especially during a pandemic, are also relatively small on a global scale. Finland holds 49.1 tonnes and Sweden 125.7 tonnes of gold accounting for 0.14% and 0.35%, of the world's reserves, respectively. Norway reports no gold holdings at all (as of August 2021) (SGU, 2020; WGC, 2021b).

The following research hypothesis was formulated: the rates of return on the analysed stock markets constituted a Granger cause of the rates of return on the gold market.

The VAR model was applied in the analysis, and served as the basis for performing a Granger non-causality linear test, additionally the decomposition of variance and an analysis of the impulse response function (IRF) were included. We also curried out the Augmented Dickey–Fuller Unit Root Test (ADF test) and cointegration test for variables priori to estimating step. The study of causal relations by means of this method also used by other authors was devoted to countries which were not under investigation so far. The empirical data covered the period between September 2001 and October 2020.

The structure of this paper is organized as follows. Section 2 presents the literature review in which we discuss the results and applied method of research concerning linkages between different markets, inter alia gold and stocks, covering various countries, including in particular major producers and consumers of gold, and geographical areas. Section 3 is devoted to methodology of research describing the VAR model specification and Granger causality test procedure also expanded to include an analysis of forecast error variance decomposition (FVED) and the Impulse response function (IRF). In Section 4 we characterise the data sample and research period. Section 4 contains empirical results, namely the analysis of stationarity and cointegration of variables, causality relations, FVED, IFR. Section 5 consists of conclusion.

2. Literature review

Interrelations between various classes of assets and gold have been investigated by numerous authors. Initially, their analyses focused only on the strength and direction of correlations. The studies related to various countries, including in particular major producers and consumers of gold, and geographical areas. The authors focused on exploring the causal relationships between these variables by applying vector autoregression models (VAR) and Granger tests, based on the reduced-form VAR. Some authors also employed error variance decomposition and the impulse response function.

In most cases research was focused on interrelations between two asset classes, i.e. stocks and gold. Choudhry et al. (2015, pp. 247–256) analysed non-linear correlations between rates of return on gold in national currencies and stock, and their volatility in the period between January 2000 and March 2014, divided into two sub-periods, before the crisis through and including June 2007, and during the crisis starting in July 2007. The analysis involved the gold and stock markets in three countries, the United Kingdom, the United States and Japan. Stock market volatility was assessed on the basis of the GARCH model. A significant non-linear bilateral correlation was found between the variables in question during the crisis period, as opposed to the preceding period. Before the crisis, a causal relationship was only significant in the UK, while Japan was an exception during the crisis. Acikalin and Basci (2016, pp. 565–574) studied these interrelations on the Istanbul Stock Exchange between the BIST Gold Market Index (GOLD) and the Istanbul Stock Exchange National 100 Index (BIST 100), covering the period between 1 August 2012 and 17 March 2015 with use of the Error Correction Model as a long-term equilibrium between the BIST 100 index and gold was found. A unidirectional Granger causal relationship also occurred between BIST 100 and gold. Bhuvaneshwari and Ramya (2017, pp. 305–316) analysed causal relationships between the stock prices reflected by S&P CNX Nifty and gold market in India. The analysis covered the period between January 2011 and December 2015 on monthly basis. The stationarity of variables was tested by means of Augmented Dickey–Fuller and Phillips–Perron unit root tests. The authors found no cointegration between the gold rates and the stock index on the basis of the Johansen test applied to examine a long-term equilibrium. Causal relationship was also not indicated between the considered variables, i.e. stock prices do not have impact on gold rate. Al-Ameer, et al. (2018, pp. 357–371) dealt with examining the causal relationship between the prices of gold and stocks on the German market represented by Frankfurt Stock Exchange HDAX Index in the period between August 2004 and September 2016. Although the sample was divided into three periods, i.e. before, during and after financial crisis they reported similar results showing the existence of a long run relationship between variables under analysis and the lack of Granger causality. Mamcarz (2019, pp. 405–422) studied the causal relationships between gold and stock markets in US, Germany, Japan and Poland covering the entire period between January 1997 and March 2018, as well as during the gold bull and bear market period. The cases of bidirectional and unidirectional causality were reported depending on period/subperiods of analysis and markets. Gold was priced in domestic currencies. Tiwari et al. (2019, pp. 2172–2214) analysed correlations between gold markets and stock markets in eight countries, including seven developing countries (Brazil, China, India, Indonesia, Korea, Mexico, Russia, Turkey) in the period between January 2002 and July 2018. The authors applied an analysis of Granger causality using quantile-on-quantile regression methods. The results obtained based on QQR for the entire sample (the entire period) revealed a weak positive correlation in quantile for gold and returns on stock. After dividing the entire period into sub-periods (before and after the crisis), the overall results were similar, except for those obtained for Turkey, China and Indonesia. Based on the results of the causality test-in-mean and causality test-in-variance, no causal relationships were found in the period preceding the crisis, whereas in the period after the crisis, causality in the direction from gold to stocks was revealed in some of the markets.

Apart from assets mentioned above some authors also took crude oil into consideration in theirs' research. Crude oil prices have both impact on stock and gold prices. The increase of crude oil price raises production costs in economy and results in lower stock prices. On the other hand, the correlation between crude oil and gold is positive. This relationship can be explained by cost-push inflation associated with rising crude oil prices which can lead to increased demand for gold and higher prices of this precious metal as a result since investors allocate their capital to gold perceived as a hedge against inflation. Singh (2014, pp. 1265–1274) studied causal relationships between the Indian stock, gold and oil markets. Based on the results of the cointegration test, author found the existence of a long-term equilibrium between the stock and oil markets and gold prices. The Granger test results showed a unidirectional causality between the stock market index and the price of gold, and between the oil price and the stock market index. Bouri et al. (2017, pp. 201–206) analysed global markets to find correlations between gold, oil and the Indian stock market in the period between June 2009 and May 2016. The authors applied the implied-volatility indices (VIX) in order to examine cointegration and non-linear causality between these markets. They found a cointegrating relationship and a non-linear positive effect of the implied volatility of gold and oil prices on the stock market under analysis. They revealed a reverse bidirectional causality between implied volatility, the gold prices and the oil prices. Tursoy and Faisel (2018, pp. 49–54) analysed correlations between stock, gold, and oil prices on the Turkish market covering the period between January 1986 and November 2016. They applied ARDL model. The authors stated that both in the long-term and short-term perspective, there was a negative correlation between gold prices and stock prices, and a positive correlation between oil prices and stock prices. The results of the Granger causality test revealed unidirectional causality between the gold price and the stock price.

The next variable of interest is the exchange rate. Gold is priced in USD and is negatively correlated with the values of domestic currencies expressed in USD. Sujit and Kumar (2011, pp. 145–165) explored the interrelations between such variables as prices of gold and stock (S&P500) and exchange rates and crude oil prices (WTI, Brent) in the period between 2 January 1998 to 5 June 2011. They applied two VAR models and cointegration analysis in their studies. The first model took into consideration the relationship between Gold (USD), WTI, exchange rate, and S&P, while the second one analysed Brent oil prices, exchange rates, WTI, and Gold (EUR). They observed a significant impact of the exchange rate on the other variables, and a limited impact of stock prices on exchange rates. As regards the second model, a weak long-term correlation between the variables was revealed. The authors also employed the impulse response function, and error variance decomposition as a tool of a detailed analysis. Singh and Sharma (2018, pp. 365–376), performed an analysis of cointegration and causal relationships between gold, Dollar exchange rates and the stock market (Sensex index) covering the global crisis period in 2008. The Granger test based on VAR/VCEM and decomposition of variance were applied to assess causal relationships. Tests of cointegration, causality strength and direction covered three sub-periods: before, during and after the crisis. The Granger test confirmed the existence of a unidirectional causality from the Dollar and Sensex index to the oil and gold prices, and from the Sensex to the Dollar. The relationship between these variables was dynamic, and was the outcome of the 2008 global economic crisis. Akbar et al. (2019, pp. 154–164) examined the dynamic relationships between gold, stock, exchange rates and interest rates in Pakistan in the period between January 2001 and December 2014. They applied the classic VAR model and the Bayesian VAR model. The authors analysed correlations in the short-term perspective as no cointegration was reported. The results showed a reverse bilateral correlation between stock and gold prices, and between Rupee exchange rates and gold, while a positive bilateral correlation was found between stock prices and Rupee exchange rates. Based on the impulse response function analysis, the authors found that volatility in stock, gold and foreign exchange markets was interrelated. Fluctuations in exchange rates caused stock and gold prices to move in the reverse direction.

To sum up the results concerning the relationship between stock and gold presented in this section the bilateral causality was indicated as the most frequent. The unidirectional causality from gold to stock was in the second place and the relationship in the opposite direction appeared the least often. The number of additional variables was insignificant. The results confirm that investors allocated capital from stock to gold market and vice versa. The cases of the lack of causality were relatively rare. To asses and compare results we should however consider that some authors applied different methods (models) and their research covered various periods.

3. Methods

Empirical studies were based on data from the stock markets and the gold market in three Nordic countries — Finland, Sweden and Norway — covering the period between September 2001 and October 2020, represented by the following stock indices of the Helsinki Stock Exchange (OMXH25), Stockholm Stock Exchange (OMXS30) and Oslo Stock Exchange (OSEAX) and gold prices in Euro, Swedish Krona and Norwegian Krone (end-of-month data). The study sample consisted of 230 observations of monthly logarithmic rates of return. Empirical data on the indices values were obtained from the Nasdaq (2021) and Oslo Børs (2021), while the data on gold prices and exchange rates were obtained from the World Gold Council (WGC, 2021a) and Stooq (2021), respectively.

On the basis of the model presented below the following research hypothesis was verified: the rates of return on the analysed stock markets constituted a Granger cause of the rates of return on the gold market.

Granger causal relationships were analysed by applying the VAR Model (Vector Autoregressive Model) in its standard form (reduced-form VAR model). As no long-term relationships between the non-stationary variables expressed in logarithms were indicated while applying the cointegration analysis: the Engle–Granger procedure (the ADF test for residuals) and the Johansen test, there was no need to supplement the VAR model with the Error Correction Mechanism (ECM). In the case of the Johansen test the null hypothesis, assuming that the VAR model had no cointegration vectors (H0: r=0) was tested against an alternative hypothesis (H1: r≤1) and could not be rejected (see Charemza & Deadman, 1997, p. 129, 175; Johansen & Juselius, 1990, pp. 169–210).

The two-dimensional VAR(p) model in the reduced-form, revealing the relationships between pairs of variables in the form of logarithmic rates of return (first differences of logarithms) on the indices of selected stock and gold markets, can be described with the use of the following formula (compare Gujarati, 2003, p. 697):

$$\Delta y_t = \sum\nolimits_{i=1}^{p-1} \alpha_i \Delta z_{t-i} + \sum\nolimits_{j=1}^{p-1} \beta_j \Delta y_{t-j} + e_{1t}, \tag{1}$$

$$\Delta z_t = \sum\nolimits_{i=1}^{p-1} \gamma_i \Delta z_{t-i} + \sum\nolimits_{j=1}^{p-1} \delta_j \Delta y_{t-j} + e_{2t}, \tag{2}$$

where:

Δy_t — logarithmic rate of return on *i*-th stock index;

Δz_t — logarithmic rate of return on investments in gold;

$\alpha, \beta, \gamma, \delta$ — structural parameters of the model;

e_{it} — random parameter of *i*-th equation;

p — number of lags based on information criterion (AIC, BIC, HQC).

The advantage of applying the VAR model is that if we are not sure which variable is in fact exogenous it is possible to treat all of them symmetrically, i.e. the time path of Δy_t can be influenced by current and previous realizations of Δz_t and vice versa. This means that we do not a priori divide variables into endo- and exogenous. Reasoning for such approach was presented in detail by Sims (1980, pp. 1–48).

Causal relationships were examined with the use of the Granger test to define whether variable Δz_t was a Granger cause of Δy_t ($\Delta z \rightarrow \Delta y$) (Equation 1). A relationship in the reverse direction ($\Delta y \rightarrow \Delta z$) was tested on the basis of Equation 2 (compare Charemza & Deadman, 1997, p. 165). The F-test of the significance of parameters $\Sigma\alpha_i$ and $\Sigma\delta_i$ respectively made it possible to determine the nature of the causal relationships (unidirectional, bidirectional, or no causality), (see Gujarati, 2003, p. 698).

The stationarity of the variables was a prerequisite for applying the procedure. Correlation coefficients were also calculated for the first differences of the variables in order to eliminate spurious regression. The calculations were performed using the GRETL software.

In the next step, the analysis of Granger causal relationship was expanded to include an analysis of error variance decomposition and the impulse response function (IRF), with a view to defining in greater detail the correlations between the variables being analysed in this study. These tools also facilitate the assessment of system stability. Further investigation involved the reduced-form model to be transformed into its structural form (see Enders, 2010, p. 298; Kusideł, 2000, pp. 99–113). In order to obtain an impulse response function presenting the behaviour of variables Δy_t and Δz_t in response to various shocks the Cholesky decomposition which leads to imposing of an appropriate number of restrictions (i.e. ordering of variables) on the parameters of Matrix B in the structural model was applied to retrieve structural disturbances from the residuals of the estimated VAR model (Enders, 2010, pp. 306–308, Kusideł, 2000, pp. 99–113).

To carry out an analysis of the influence of a given shock (impulse) on the entire system, the so-called IRF analysis we plot an IRF function of the coefficients $\varphi_{jk}(i)$ relative to time *i*. This is a practical way of representing how variables Δy_t and Δz_t react to various shocks (Enders, 2010, p. 308).

The Cholesky decomposition (also referred to as Cholesky factorisation) requires imposing the appropriate number of restrictions on matrix B parameters in the structural model, which implies making the corresponding assumption on the order of variables (equations) (Enders, 2010, pp. 306–307):

– if Δy_t, Δz_t, i.e. parameter $b_{12}=0$; then variable Δy_t will simultaneously impact on Δz_t, and Δz_t will impact on Δy_t with a one-period lag;
– if Δz_t, Δy_t, i.e. parameter $b_{21}=0$; then variable Δz_t will simultaneously impact on Δy_t, and Δy_t will impact on Δz_t with a one-period lag (in other words, shock ε_{yt} and ε_{zt} will simultaneously determine the value of variable Δy_t, and shock ε_{zt} will determine only the value of variable Δz_t).

The number of zero-values of matrix B elements is established using the formula $(n^2-n)/2$, for the VAR model with n variables.

A forecast error variance decomposition defines the extent to which changes into Δy_t and Δz_t can be assigned to their own shocks, and to what extent they can be assigned to the shocks to the other variable. The error variance decomposition was performed also considering various order of variables. Such an arrangement allows the distinction between the most exogenous variables and endogenous variables (which are the most dependent on the other variables). This can influence the quality of the study, since a different order of model equations (variables) can determine the results. Hence, the author performed the analysis for two possible equation arrangements to allow a comparison of how the variance structure changes. The stronger the correlations between residuals from subsequent equation models, the larger the differences between the results (Enders, 2010, pp. 314–315).

4. Results

The subject of the analysis of causal interrelations included four time series: the price of gold and three stock indices (OMXH25, OMXS30 and OSEAX). The basic descriptive statistics of time series of the variables under analysis are shown in Table 1, and their interrelations are illustrated in Chart 1. and 2.

According to data in Table 1, the Finnish market exhibited the greatest stock price fluctuations in absolute terms (standard deviation of 907.69). The largest collapse of the stock market, in relation to the other countries under analysis, could be observed during the economic crisis. Out of the time series related to stock markets, the OSEAX index was characterised by the greatest volatility (48.64%), followed by OMSX25 (34.31%) and OMX30 (31.78%). Two indices (OMXH25, OSEAX) were characterised by right-skewed and platykurtic distributions, which meant weak concentration around the mean value as compared to normal distribution (a mesokurtic distribution), while (OMXS30) was characterised by left-skewed. As regards prices of gold in domestic currencies, the highest volatility was recorded for gold prices in NOK (51.71%), followed by prices in SEK (47.20%) and in EUR (44.96%, Finland). Only the price of gold in EURO was characterised by left-skewed and platykurtic distributions while expressed in SEK and NOK was right-skewed. All the variables under analysis exceeded the minimum required value for a volatility coefficient (V>10.0%), which meant that the conditions for model analysis were satisfied.

The prices of gold in all domestic currencies showed a similar development trend. However, apart from few short periods, they did not correspond to the changes in the stock markets in individual countries (Chart 1 and Chart 2). In the periods in which these markets collapsed, investors could choose gold as an alternative to stock. Further in this study, variables expressed as logarithms were applied to facilitate the transformation of non-linear correlations to linear correlations.

In the next step the order of time series integration was determined with the use of the ADF test (the Augmented Dickey–Fuller Unit Root Test). The results are shown in Table 2.

The unit root test showed that time series were integrated of order 1, as it was impossible to reject the null hypothesis on the non-stationarity of series with a significance level of α=0.01. The differentiation of series (the first difference) made it possible to obtain stationary variables. In that case analysis of cointegration between non-stationary variables is justified.

The results concerning the Engle–Granger cointegration test for series of logarithms (index, gold price) integrated of order 1 shows that there are no grounds for rejecting the null hypothesis on non-stationarity of residuals obtained for models which constitute the linear combinations of these variables (the ADF test for residuals). The statistics of the Johansen cointegration test (the matrix trace test, the maximum eigenvalue test) also confirm that the null hypothesis, which assumes that there are no cointegrating vectors in the VAR model, cannot be rejected (H0: r=0). The zero rank of matrix Π was found, which means that the variables were not cointegrated at all standard significance levels. Therefore, it was assumed that no long-term relationship occurred between the pairs of the variables (Table 3).

The Granger causality test was performed using the VAR model based on first differences of the variables without the error correction component, due to the integration of order 1 of the model variables and the lack of cointegration. The first differences of variable expressed in logarithms in the model corresponded to the logarithmic rates of return on investments (R) on selected stock markets and investments in gold. As regards the stationary variables (first differences), no spurious correlation was revealed. The correlation coefficients between those rates of return are presented in Table 4.

Data in Table 4 shows that the values of the Pearson's linear correlation coefficients were statistically significant in two instances. The correlation between the rates of return on investments on the three stock markets and in gold was negative. Statistical significance was revealed only between returns on gold and two stock indices respectively: R_OMXS30 (a weak correlation, α=0.1) and R_OSEAX (a weak correlation, α=0.01).

The optimal number of lags was determined on the basis of the Akaike Information Criterion, Schwartz Criterion (SIC), and the Hannan–Quinn Criterion (HQC), and it amounted to 1 or 2 (Table 5). In the end VAR(1) models were estimated.

Table 6 shows the results of the overall significance of parameters and of the Shapiro–Wilk residuals normality test for the estimated models (Equation 1 and Equation 2 respectively).

The results of the Granger test performed on the analysed models relating to the rates of return on investments in gold and on the selected stock markets did not reveal causality, apart from one instance. Changes in gold prices constituted a Granger cause of changes in stock prices only in Norway, on the Oslo Stock Exchange, provided that the significance level had been slightly increased from the standard 0.1 to 0.14. In the other cases, no causality between the rates of return on those assets was found. The model residuals did not have a normal distribution.

Granger causality between the rates of return related to individual variables was found only in one instance out of six possible combinations. Additional tools to verify the results included error variance decomposition and the impulse response function. The quality of the error variance decomposition results was determined by the degree of correlation of residuals $\left(\rho_{12}^{i}\right)$ from individual model equations (Table 7).

As shown in Table 7, correlation coefficients between residuals of subsequent model equations were very low, and had negative values. Only two of them were statistically significant at α=0.01 (Model 3) and α=0.1 (Model 2).

The results of the error variance decomposition analysis for a 24-month forecast horizon for individual models estimated on the basis of rates of return on stock indices (Δy_t) and on gold (Δz_t), considering the varying order of equations, are listed in Tables 8, 9 and 10. The differences between the results should grow as the correlation between residuals from the subsequent equation models increases (cf.: Model 3). What seemed to be of key significance for the evaluation of the correlations between the variables is the interpretation of the last period (last table row).

According to data in Table 8, after the change to the order of equations (Δy_t, Δz_t vs. Δz_t, Δy_t) the results were subject to slight modifications (line 4–24: 99.71% versus 99.19% for R_OMXH25, and 99.57% versus 99.96% for R_GOLD_EUR). The effect of the variable R_GOLD_EUR on the variable R_OMXH25 increased slightly (0.29% versus 0.81%), while the variable R_GOLD EUR became more independent of the variable R_OMXH25 (0.43% versus 0.04%). Apart from the aforementioned instances of minor variations in analysis results following the change to the order of equations, it is evident that the results are similar. The variables are in fact explained by their own values, with no correlation with random elements $\left(\rho_{12}^{1} = 0.079752858,\ p = 0.2476\right)$. Such high independence in the model variables confirms the results of the Granger test (no causality, Model 1).

According to the data in Table 9, considering the order of the variables from Δy_t to Δz_t, and the reverse order from Δz_t to Δy_t, the variance components are stabilised. In both instances, the variables are largely explained by their own values. Given the highest values expressing the relationships between the variables, the analysis revealed only an insignificant effect of the variable R_OMXS30 on R_GOLD_SEK (1.82%) for the order of the variables from Δy_t to Δz_t, the effect of the variable R_GOLD_SEK on the variable R_OMXS30 (2.33%) for the reverse order from Δz_t to Δy_t (the last line of Table 9). Although the random parameters of the variables in this model are more closely correlated compared with Model 1 $\left(\rho_{12}^{2}=-0.124764064, \mathrm{p}=0.0698 \text{ versus } \rho_{12}^{1}=-0.079752858, \mathrm{p}=0.2476\right)$, this still means that no linear relationship was found. This practically demonstrates that no correlation (no causality) existed between rates of return on the assets under analysis, irrespective of the order of model equations.

Table 10 shows that the variables in this model were less explicable by their own values in relation to previous models. This applies to the variable R_GOLD_NOK, which is influenced in 4.19% by variable R_OSEAX, considering the order of the variables from Δy_t to Δz_t, and to the variable R_OSEAX, determined at 5.83% by R_GOLD_NOK, for the reverse order of the variables. Random elements were characterised by an average correlation $\left(\rho_{12}^{3}=-0.183751162, \mathrm{p}=0.0073\right)$, thus the ordering of equations was more justifiable in this case. Since differences in the results were found, it can be inferred that the change of the equation order affected them (line 4–24: 99.07% versus 94.17% for R_OSEAX, and 95.81% versus 99.75% for R_GOLD_NOK). The effect of R_GOLD_NOK on R_OSEAX increased (5.83% versus 0.93%), while the effect of the variable R_OSEAX on the variable R_GOLD_NOK decreased (4.19% versus 0.25%). In this aspect, the variable R_GOLD_NOK should be treated as a priority variable, more independent of the stock market in Norway in relation to the opposite causality. The results were confirmed by the Granger causality analysis, i.e. a unidirectional dependence of the stock market from R_GOLD_NOK, but only after the significance level had been increased from the standard 0.1 to 0.14.

The values of the impulse response function (caused by shocks in rates of return from stock investment — part a and gold part — b) in individual models are shown in Charts 3a, 3b, 5a, 5b, 7a, 7b according to the order of equations from Δy_t to Δz_t, while Charts 4a, 4b, 6a, 6b, 8a, 8b consider the reverse order of equations from Δz_t to Δy_t. The forecasting horizon covers 24 months.

In all models, the impulse response functions are similar regardless of the adopted order of equations. Such a situation occurs where there is a weak correlation between residuals from individual equations of analysed models This is visible in Model 1 and 2. Insignificant discrepancies in the function shape can be observed during shock periods. Both positive and negative responses of individual variables to shocks can be observed in all Charts. The longest disturbance period lasted 5 to 4 months, after which time they disappeared quickly. This means that the values of the impulse response function converged to zero as the time horizon extended. This proved that the constructed models are robust. In addition, the impulses which were suppressed quickly did not cause variables to fluctuate significantly. This demonstrated their strong independence. This was also confirmed by the earlier causality analysis and error variance decomposition.

5. Conclusion

The direction of causality between the analysed variables is reflected by the fact that investors tend to transfer their assets from gold markets to more profitable markets, or return to gold markets. There is a large body of studies concerned mainly with the relationship between gold markets and the markets of numerous other assets, including stock markets, which are the focus of this paper. The results suggest the existence of both unidirectional causality between gold and stock markets, and a reverse relationship, and even the lack of such a causality. The studies covered various periods and countries, moreover authors applied different research methods (models). In these circumstances the results are not fully comparable. To our knowledge no similar research was devoted to interrelations between stock and gold markets of Nordic countries included in this paper.

The results proved that, both in the case of Nordic countries considered in our research and many countries analysed by other authors no Granger causality occurred in either direction at standard significance levels Al-Ameer, et al. (2018, pp. 357–371), Bhuvaneshwari and Ramya (2017, pp. 305–316), Choudhry et al. (2015, pp. 247–256), Mamcarz (2019, pp. 405–422), Tiwari et al. (2019, pp. 2172–2214). One instance of unidirectional causality was identified in Norway where the rate of return on the gold market was the Granger cause of the rate of return on the stock market, but only after the significance level was increased from the standard 0.1 to 0.14. The result was confirmed by error variance decomposition and the impulse response function. The changes in the stock market prices in the other two countries (Sweden, Finland) did not affect decisions made by investors who had invested in gold, and did not determine changes in the price of gold, and vice versa. The study results refuted the research hypothesis stating that the rates of return on the stock markets in three Nordic countries (Finland, Sweden, Norway) were the Granger causes of rates of return on gold. In this case, non-interest-yielding investments in gold did not represent an alternative to investments in stock. This is significant because investors who intend to invest their assets in stock markets in the Nordic countries which are analysed here have the opportunity to become familiar with the conditions in this region, and compare them to other markets, including major global markets which have been widely discussed in the literature on the subject. The results of my research should prove useful for investors who will be able to make good investment choices.

One can assume that rapid increase in gold prices due to COVID-19 pandemic lasted a relatively short time (i.e. period from January to October 2020 covered in paper) to have a significant impact on obtained results. There is no doubt that economic slowdown and record high gold price in many currencies will affect the demand for gold as well as interrelations between analysed markets. This will be the field of further research.

References

Acikalin, S., & Basci, E.S. (2016). Cointegration and causality relationship between BIST 100 and BIST gold indices. *Journal of Management and Economics*, 23(2), 565–574. https://doi.org/10.18657/yecbu.53293.

Akbar, M., Iqbal, F., & Noor, F. (2019). Bayesian analysis of dynamic linkages among gold price, stock prices, exchange rate and interest rate in Pakistan. *Resources Policy*, 62, 154–164. https://doi.org/10.1016/j.resourpol.2019.03.003.

Al-Ameer, M., Hammad, W., Ismail, A., & Hamdan, A. (2018). The relationship of gold price with the stock market: the case of Frankfurt Stock Exchange. *International Journal of Energy Economics and Policy*, 8(5), 357–371.

Bhuvaneshwari, D., & Ramya, K. (2017). Causal relationship between stock prices and gold rate: empirical evidence from India. *Afro-Asian Journal of Finance and Accounting*, 7(4), 305–316. https://doi.org/10.1504/AAJFA.2017.087502.

Bouri, E., Jain, A., Biswal, P.C., & Roubaud, D. (2017). Cointegration and non-linear causality amongst gold, oil, and the Indian stock market: evidence from implied volatility indices. *Resources Policy*, 52, 201–206. https://doi.org/10.1016/j.resourpol.2017.03.003.

Charemza, W.W., & Deadman, D.F. (1997). *New directions in econometric practice: general to specific modelling, cointegration and vector auto-regression*. Edward Elgar.

Choudhry, T., Hassan, S.S., & Shabi, S. (2015). Relationship between gold and stock markets during the global financial crisis: evidence from nonlinear causality tests. *International Review of Financial Analysis*, 41, 247–256. https://doi.org/10.1016/j.irfa.2015.03.011.

Enders, W. (2010). *Applied econometric time series*. Wiley & Sons.

Gujarati, D.N. (2003). *Basic econometrics*. McGraw Hill.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration with applications to the demand for money. *Oxford Bulletin of Economics & Statistic*, 52(2), 169–210. https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x.

Kusideł, E. (2000). Application of structural VAR models and impulse response function. *Dynamic Econometric Models*, 4.

Mamcarz, K. (2019). Gold market and selected stock markets-granger causality analysis. In W. Tarczyński, & K. Nermend (Eds.), *Effective investments on capital markets* (pp. 405–422). Springer. https://doi.org/10.1007/978-3-030-21274-2_28.

Nasdaq. (2021). Retrieved 19.11.2020 from http://www.nasdaqomxnordic.com.

Oslo Børs. (2021). Retrieved 19.11.2020 from https://www.oslobors.no/ob_eng.

SGU. (2020). *Bergverksstatistik 2019: statistics of the Swedish mining industry 2019*. Retrieved 23.10.2021 form https://resource.sgu.se/produkter/pp/pp2020-1-rapport.pdf.

Sims, C. (1980). Macroeconomics and reality. *Econometrica*, 48(1), 1–48. https://doi.org/10.2307/1912017.

Singh, D. (2014), The dynamics of gold prices, crude oil prices and stock index comovements: cointegration evidence of India. *Finance India*, 28(4), 1265–1274.

Singh, N.P., & Sharma, S. (2018). Cointegration and causality among dollar, oil, gold and sensex across global financial crisis. *Vision: The Journal of Business Perspective*, 22(4), 365–376. https://doi.org/10.1177/0972262918804336.

Stooq. (2021). Retrieved 19.11.2020 from https://stooq.pl.

Sujit, K.S., & Rajesh, K.B. (2011). Study on dynamic relationship among gold price, oil price, exchange rate and stock market returns. *International Journal of Applied Business and Economic Research*, 9(2), 145–165.

Tiwari, A.K., Adewuyi, A.O., & Roubaud, D. (2019). Dependence between the global gold market and emerging stock markets (E7+1): evidence from Granger causality using quantile and quantile-on-quantile regression methods. *The World Economy*, 42(7), 2172–2214. https://doi.org/10.1111/twec.12775.

Tursoy, T., Faisal F. (2018). The impact of gold and crude oil prices on stock market in Turkey: empirical evidences from ARDL bounds test and combined cointegration. *Resources Policy*, 55, 49–54. https://doi.org/10.1016/j.resourpol.2017.10.014.

WGC. (2021a). *Gold price in a range of currencies since 1978 (xlsx)*. Retrieved 19.11.2020 from https://www.gold.org/goldhub/data/gold-prices.

WGC. (2021b). *Monthly central bank statistics*. Retrieved 23.10.2021 from https://www.gold.org/goldhub/data/monthly-central-bank-statistics.

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Appendix

Table 1.
The descriptive statistics of time series OMXH25, OMXS30, OSEAX and gold price (in domestic currencies) in the period from 2001 (September) to 2020 (October)

Variable	Mean	Median	Min	Max
OMXH25	2645.30	2566.40	1107.4	4353.7
OMXS30	1136.20	1103.20	445.65	1829.4
OSEAX	524.13	494.83	109.02	1069.1
GOLD_EUR	835.40	958.90	301.30	1661.7
GOLD_SEK	7980.90	8570.20	2747.80	17248.0
GOLD_NOK	7287.50	7812.00	2328.70	17956.0
Variable	Standard deviation	Coefficient of variation	Skewness	Kurtosis
OMXH25	907.69	0.3431	0.2112	−1.1075
OMXS30	361.07	0.3178	−0.0094	−1.1148
OSEAX	254.94	0.4864	0.2817	−0.7461
GOLD_EUR	375.60	0.4496	−0.0018	−1.2043
GOLD_SEK	3767.30	0.4720	0.2071	−0.7513
GOLD_NOK	3768.40	0.5171	0.5034	−0.1387

Notes:

EUR — Euro; SEK — Swedish Krona, NOK — Norwegian Krone.

Source: Own preparation.

Table 2.
ADF test results for a series of logarithms in the period from 2001 (September) to 2020 (October)

Index/gold price*	Variable Tau statistic	First difference Tau statistic
OMXH25	−1.3165 [0.6242]	−7.6173* [6.388×10^{-12}]
OMXS30	−1.0479 [0.7361]	−14.1549* [1.422×10^{-24}]
OSEAX	−1.6056 [0.4797]	−11.9663* [9.797×10^{-21}]
GOLD_EUR	−0.8272 [0.8109]	−16.7022* [2.747×10^{-27}]
GOLD_SEK	−0.5287 [0.8819]	−16.2947* [5.358×10^{-27}]
GOLD_NOK	−0.1896 [0.9375]	−5.77466* [4.094×10^{-7}]

Notes:

* variables expressed in logarithm, p-value in square brackets, H0 is rejected for the significance level: *α=0.01.

Source: Own preparation.

Table 3.
Engle–Granger's cointegration test and Johansen cointegration test

Model/Variables*	Engle–Granger Statistics		[p-value]	
1. OMXH25; GOLD_EUR	−2.0099		[0.5228]	
2. OMXS30; GOLD_SEK	−2.7762		[0.1734]	
3. OSEAX; GOLD_NOK	−2.2962		[0.3748]	
Model/Variables*	Johansen Test Statistic [p-value]			
	Rank r	Eigen-value	Trace	Max-Eigen
OMXH25; GOLD_EUR	0	0.0251	7.0662 [0.5762]	5.5343 [0.6771]
	1	0.0070	1.5320 [0.2158]	1.5320 [0.2158]
OMXS30; GOLD_SEK	0	0.0376	9.6771 [0.3121]	8.3450 [0.3527]
	1	0.0061	1.3321 [0.2484]	1.3321 [0.2484]
OSEAX; GOLD_NOK	0	0.0339	9.4940 [0.3276]	7.5261 [0.4377]
	1	0.0090	1.9679 [0.1607]	1.9679 [0.1607]

Notes:

* variables expressed in logarithms, p-value in square brackets.

Source: Own preparation.

Table 4.
Pearson's correlation coefficients between the analysed rates of return

Variables	Correlation coefficient	p-value
R_OMXH25; R_GOLD_EUR	−0.0712	0.2830
R_OMXS30; R_GOLD_SEK	−0.1248***	0.0593
R_OSEAX; R_GOLD_NOK	−0.1955*	0.0030

Notes:

R — logarithmic rate of return on *i*-th asset, H0 is rejected for the significance level: *α=0.01; **α=0.05; ***α=0.1.

Source: Own preparation.

Table 5.
The optimal number of lags (p) for VAR models by information criterion

Model/information criterion	AIC	SIC	HQC
1. (R_OMXH25; R_GOLD_EUR)	2* [−6.3589]	1* [−6.2398]	1* [−6.2975]
2. (R_OMXS30; R_GOLD_SEK)	2* [−6.4857]	1* [−6.3838]	1* [−6.4415]
3. (R_OSEAX; R_GOLD_NOK)	2* [−6.2854]	1* [−6.1438]	2* [−6.2201]

Notes:

* optimal number of lags, information criterion value in square brackets.

Source: Own preparation.

Table 6.
The results of the F-test for the overall significance of VAR model parameters and the Shapiro–Wilk residuals normality test

Model	Null hypothesis	F-test statistics	Normality test statistic
1.	R_GOLD_EUR ↛ R_OMXH25	0.6706 [0.4137]	0.9465* [1.9462 x 10^{-7}]
	R_OMXH25 ↛ R_GOLD_EUR	0.1038 [0.7476]	0.9862** [0.0264]
2.	R_GOLD_SEK ↛ R_OMXS30	1.5218 [0.2186]	0.9605* [6.1419 x 10^{-6}]
	R_OMXS30 ↛ R_GOLD_SEK	0.8708 [0.3517]	0.9866** [0.0310]
3.	R_GOLD_NOK ↛ R_OSEAX	2.2465 [0.1353]	0.9785* [0.0015]
	R_OSEAXS30 ↛ R_GOLD_NOK	0.5910 [0.4428]	0.9853** [0.018]

Notes:

Significance level: *α=0.01; **α=0.05; ***α=0.1; p-value in square brackets.

Source: Own preparation.

Table 7.
Pearson's correlation coefficients between residuals of the analysed models

Model	Variables	Correlation coefficient $\left(\rho_{12}^{i}\right)$	p-value
1.	R_OMXH25; R_GOLD_EUR	−0.0645	0.3324
2.	R_OMXS30; R_GOLD_SEK	−0.1254***	0.0587
3.	R_OSEAX; R_GOLD_NOK	−0.20314*	0.0021

Notes:

i – *i*-th model, H0 is rejected for the significance level: *α=0.01; **α=0.05; ***α=0.1.

Source: Own preparation.

Table 8.
Forecast Error Variance Decomposition for Model 1 (R_OMXH25; R_GOLD_EUR)

Forecasting horizon (month)	R_OMXH25 percent of variance due to the shocks		R_GOLD_EUR percent of variance due to the shocks	
	R_OMXH25	R_GOLD_EUR	R_OMXH25	R_GOLD_EUR
	Ordering of variables: Δy_t, Δz_t			
1	100.0000	0.0000	0.4158	99.5842
2	99.7149	0.2851	0.4311	99.5689
3	99.7142	0.2858	0.4314	99.5686
4–24	99.7141	0.2859	0.4314	99.5686
	Ordering of variables: $[\Delta z_t, \Delta y_t]$			
1	[99.5842]	[0.4158]	[0.0000]	[100.0000]
2	[99.1892]	[0.8108]	[0.0429]	[99.9571]
3	[99.1875]	[0.8125]	[0.0430]	[99.9570]
4–24	[99.1873]	[0.8127]	[0.0430]	[99.9570]

Notes:

Results in square brakes concern alternative ordering.

Source: Own preparation.

Table 9.
Forecast Error Variance Decomposition for Model 2 (R_OMXS30; R_GOLD_SEK)

Forecasting horizon (month)	R_OMXS30 percent of variance due to the shocks		R_GOLD_SEK percent of variance due to the shocks	
	R_OMXS30	R_GOLD_SEK	R_OMXS30	R_GOLD_SEK
Ordering of variables: Δy_t, Δz_t				
1	100.0000	0.0000	1.5722	98.4278
2	99.3409	0.6591	1.8231	98.1769
3	99.3400	0.6600	1.8228	98.1772
4–24	99.3399	0.6601	1.8229	98.1771
Ordering of variables: [Δz_t, Δy_t]				
1	[98.4278]	[1.5722]	[0.0000]	[100.0000]
2	[97.6722]	[2.3278]	[0.3808]	[99.6192]
3	[97.6719]	[2.3281]	[0.3813]	[99.6187]
4–24	[97.6719]	[2.3281]	[0.3814]	[99.6186]

Notes:
Results in square brakes concern alternative ordering.

Source: Own preparation.

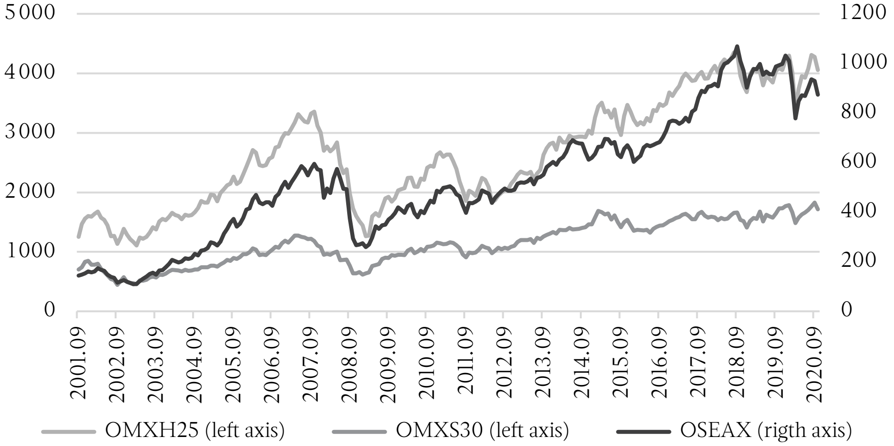
Table 10.
Forecast Error Variance Decomposition for Model 3 (R_GOLD_NOK; R_OSEAX)

Forecasting horizon (month)	R_OSEAX percent of variance due to the shocks		R_GOLD_NOK percent of variance due to the shocks	
	R_OSEAX	R_GOLD_NOK	R_OSEAX	R_GOLD_NOK
Ordering of variables: Δy_t, Δz_t				
1	100.0000	0.0000	4.1255	95.8745
2	99.0760	0.9240	4.1824	95.8176
3	99.0678	0.9322	4.1882	95.8118
4–24	99.0667	0.9333	4.1884	95.8116
Ordering of variables: [Δz_t, Δy_t]				
1	[95.8745]	[4.1255]	[0.0000]	[100.0000]
2	[94.2005]	[5.7995]	[0.2457]	[99.7543]
3	[94.1760]	[5.8240]	[0.2484]	[99.7516]
4–24	[94.1737]	[5.8263]	[0.2487]	[99.7513]

Notes:
Results in square brakes concern alternative ordering.

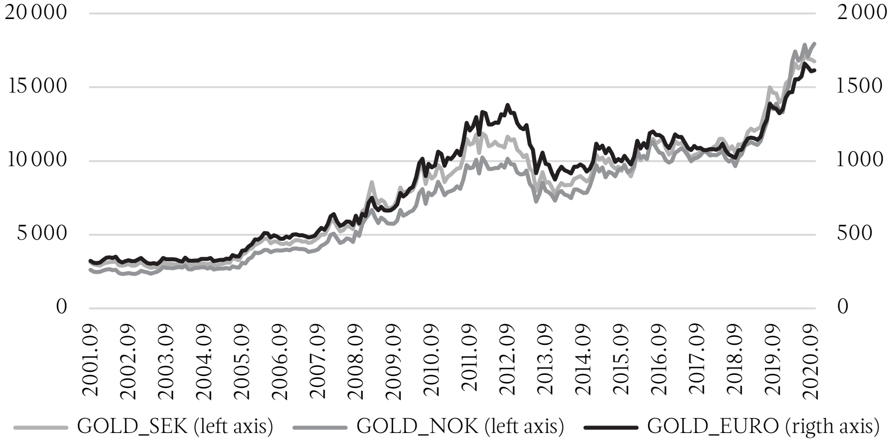
Source: Own preparation.

Chart 1.
Analysed stock indices (end of month) in the period from 2001 (September) to 2020 (October)



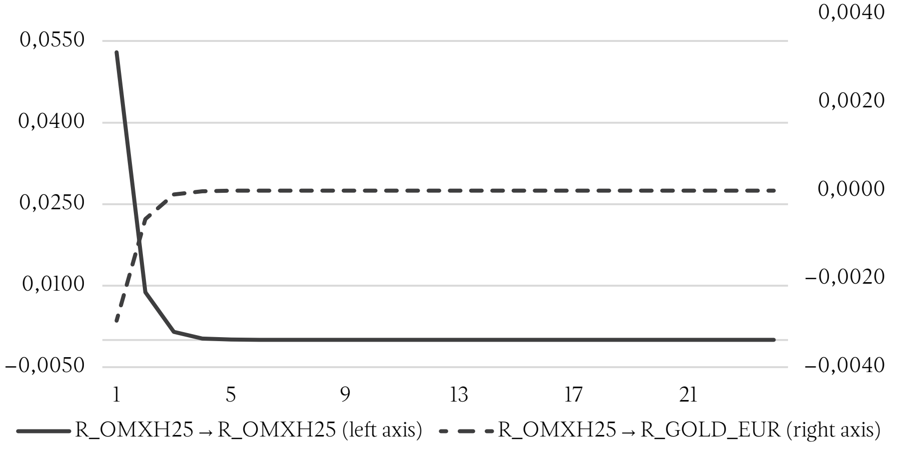
Source: Own preparation based on Nasdaq (2021), Oslo Børs (2021).

Chart 2.
Gold price in domestic currencies (end of month) in the period from 2001 (September) to 2020 (October)



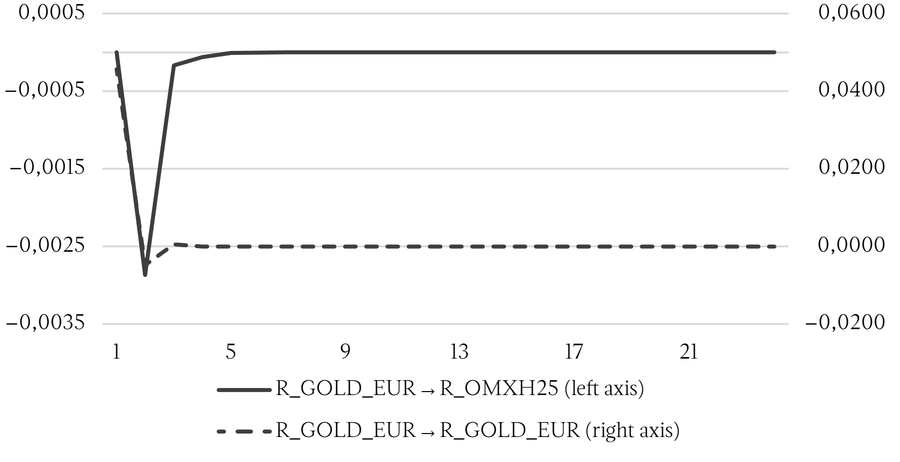
Source: Own preparation based on Stooq (2021) and WGC (2021a).

Chart 3a.
Impulse response functions of variables R_OMXH25, R_GOLD_EUR to R_OMXH25 shock (Model 1, ordering Δy_t, Δz_t)



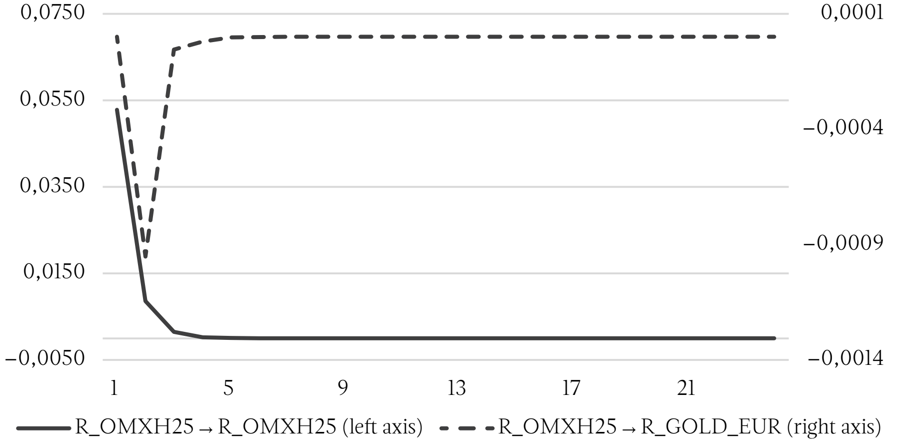
Source: Own preparation.

Chart 3b.
Impulse response functions of variables R_OMXH25, R_GOLD_EUR to R_GOLD_EUR shock (Model 1, ordering, Δy_t, Δz_t)



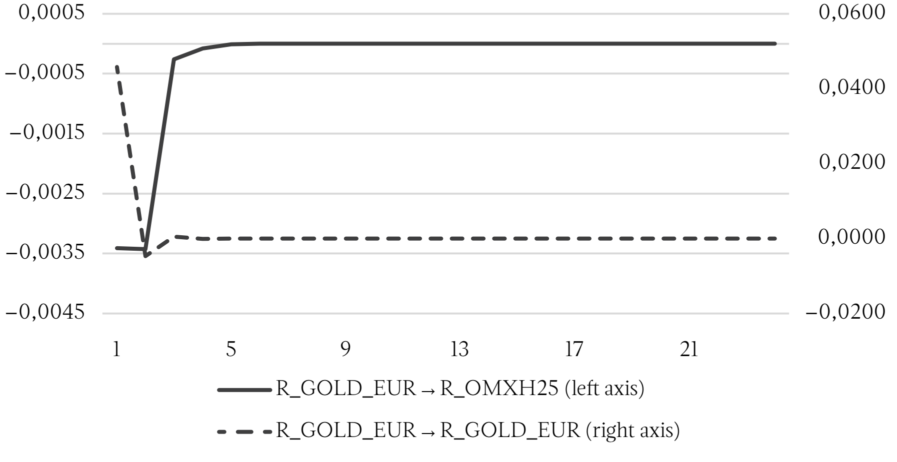
Source: Own preparation.

Chart 4a.
Impulse response functions of variables R_OMXH25, R_GOLD_EUR to R_OMXH25 shock (Model 1, ordering Δz_t, Δy_t)



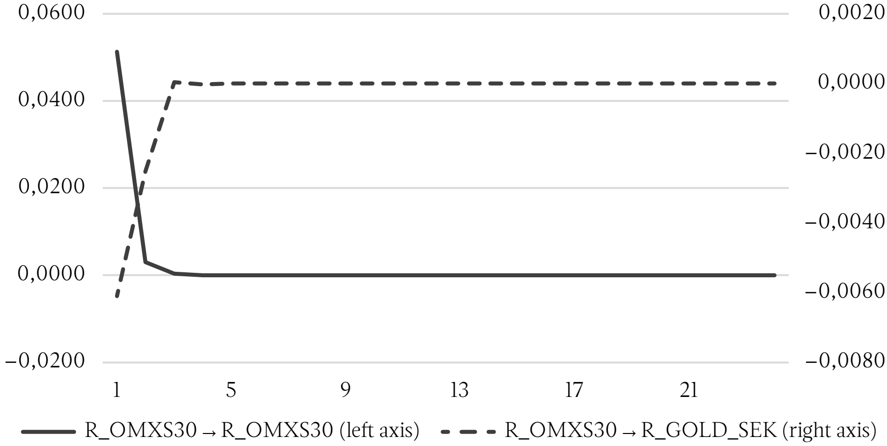
Source: Own preparation.

Chart 4b.
Impulse response functions of variables R_OMXH25, R_GOLD_EUR to R_GOLD_EUR shock (Model 1, ordering Δz_t, Δy_t)



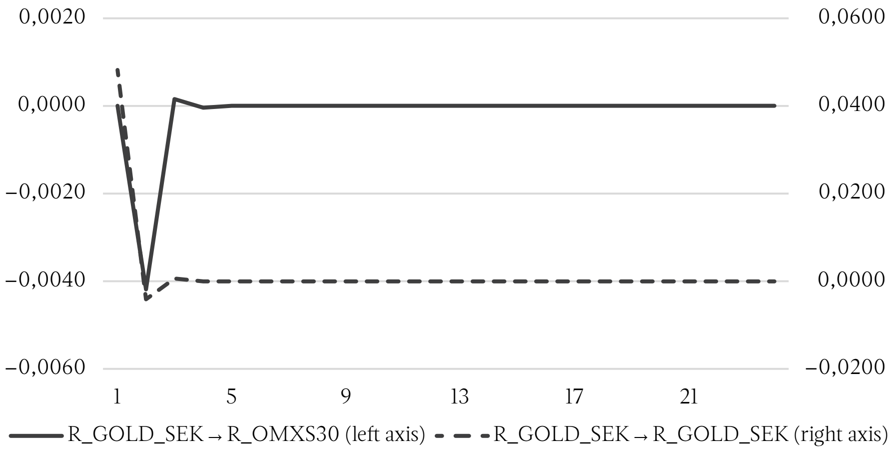
Source: Own preparation.

Chart 5a.
Impulse response functions of variables R_OMXS30, R_GOLD_SEK to R_OMXS30 shock (Model 2, ordering Δy_t, Δz_t)



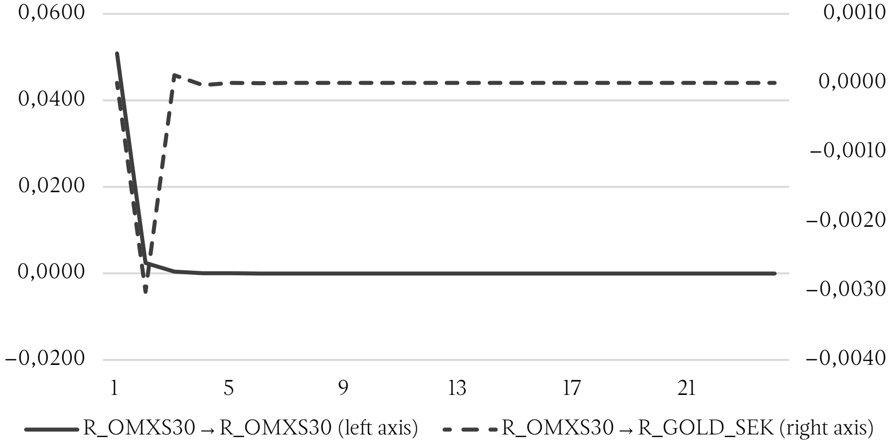
Source: Own preparation.

Chart 5b.
Impulse response functions of variables R_OMXS30, R_GOLD_SEK to R_GOLD_SEK shock (Model 2, ordering Δy_t, Δz_t)



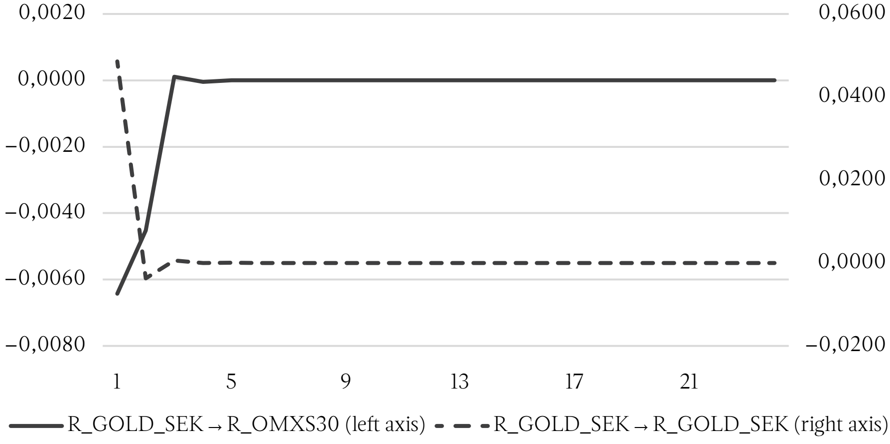
Source: Own preparation.

Chart 6a.
Impulse response functions of variables R_OMXS30, R_GOLD_SEK to R_OMXS30 shock (Model 2, ordering Δz_t, Δy_t)



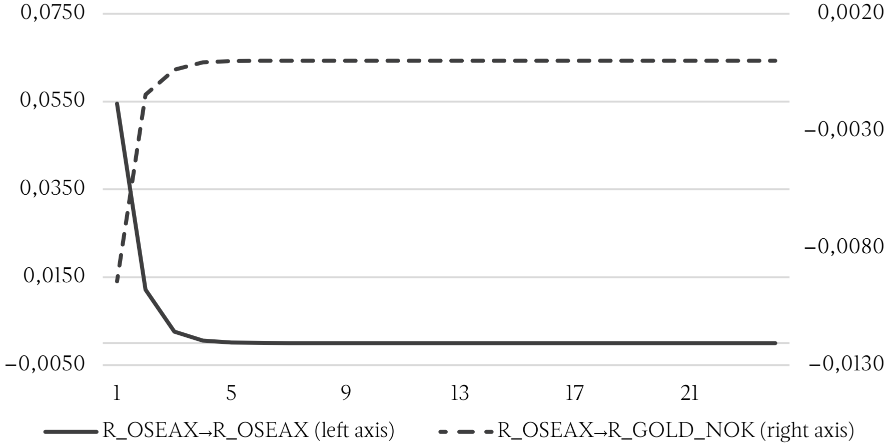
Source: Own preparation.

Chart 6b.
Impulse response functions of variables R_OMXS30, R_GOLD_SEK to R_GOLD_SEK shock (Model 2, ordering Δz_t, Δy_t)



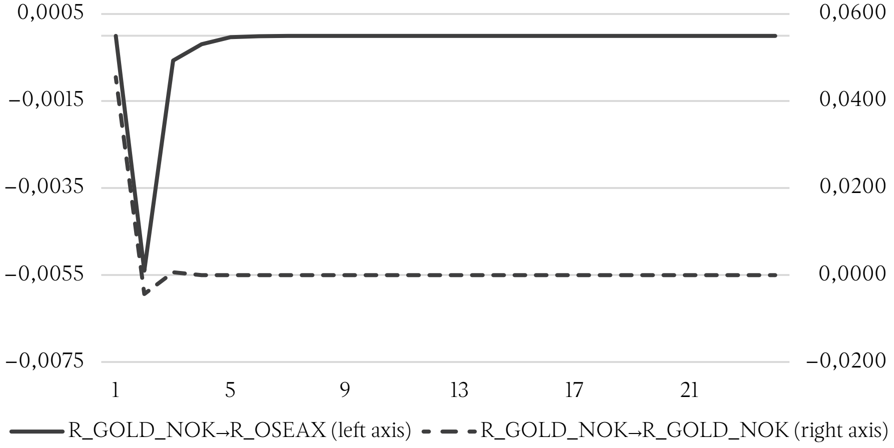
Source: Own preparation.

Chart 7a.
Impulse response functions of variables R_OSEAX, R_GOLD_NOK to R_OSEAX shock (Model 3, ordering Δy_t, Δz_t)



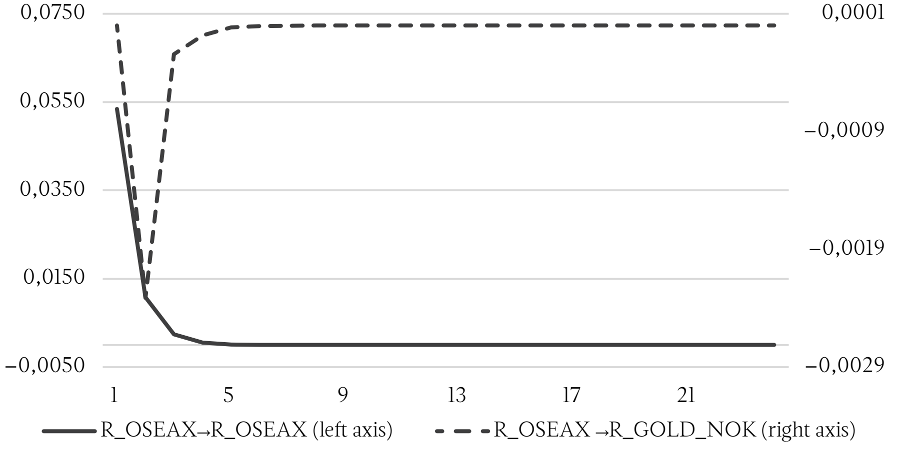
Source: Own preparation.

Chart 7b.
Impulse response functions of variables R_OSEAX, R_GOLD_NOK to R_GOLD_NOK shock (Model 3, ordering Δy_t, Δz_t)



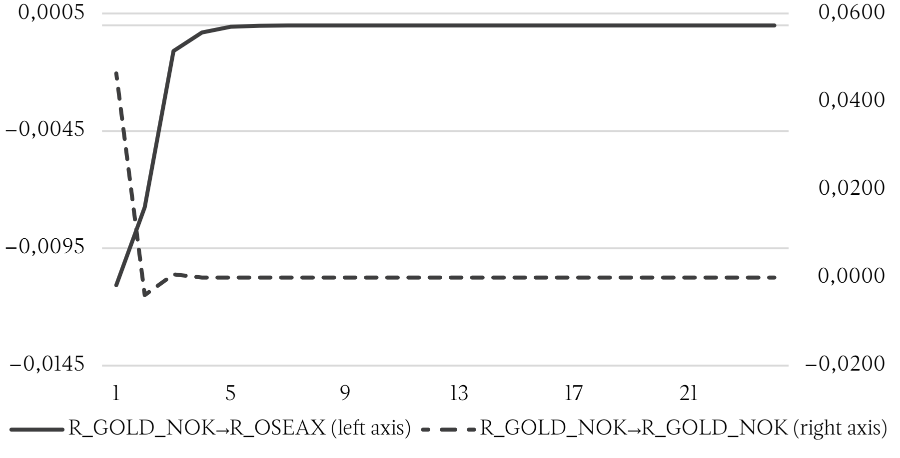
Source: Own preparation.

Chart 8a.
Impulse response functions of variables R_OSEAX, R_GOLD_NOK to R_OSEAX shock (Model 3, ordering Δz_t, Δy_t)



Source: Own preparation.

Chart 8b.
Impulse response functions of variables R_OSEAX, R_GOLD_NOK to R_GOLD_NOK shock (Model 3, ordering Δz_t, Δy_t)



Source: Own preparation.