CRUDE OIL AND GOLD MARKETS BEHAVIOR DURING CRISES

by

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Kyiv School of Economics

Abstract

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by Yuliia Pekar

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In this thesis I investigate whether gold can serve as a safe-haven asset during crises based on the analysis of financial crisis of 2008 and crisis caused by COVID-19 pandemic. I also assess whether there is a pattern of behavior for gold and crude oil during crises.

The long-run relationship of crude oil, inflation expectation and interest rate on gold price movements was found. Interest rate and inflation expectation have short term relationship with dependent variable during COVID-19 crisis. Crude oil has short-term relationship with gold prices during the financial crisis of 2008. Gold prices negatively related to crude oil prices, which supports the role of gold as a safe haven. Gold serves as a hedge against inflation as it moves in the same direction.

To my parents

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LIST OF ABBREVIATIONS

ADF. Augmented Dickey-Fuller test.

AIC. Akaike Information.

ARDL. Autoregressive Distributive Lag Model.

CPI. Consumer Price Index.

ECM. Error Correction Model.

ECT. Error Correction Term

EU. European Union.

FED. Federal Reserve System of the United States.

LBMA. London Bullion Market Association.

OPEC. The Organization of Petroleum Exporting Countries.

SBC. Schwarz Bayesian Criterion.

VAR. Vector Autoregressive.

VECM. Vector Error Correction Model

VIX. Volatility Index

WHO. World Health Organization

WTI. West Texas Intermediate.

Chapter 1

INTRODUCTION

Global financial markets confronted huge challenges during the recent outbreak of COVID-19. The pandemic has led to the global economic slowdown. To curb this extremely transmissible virus, countries around the globe have adopted massive measures, notably city closures and border closures, which in many places have brought sudden economic stoppages.

Crude oil was considered as an engine of the global economy, which affect the economy all around the world. However, the fall in the crude oil prices can bring the whole economy into uncertainty. In 2020 after the beginning of global pandemic crude oil prices have dropped below $20 a barrel, a historic minimum since the turn of the century. Later West Texas Intermediate oil price has fallen below zero in April 2020, accompanied by a fall in the world industrial production index by about 4.5% in the first quarter of 2020. This drop in the oil demand is associated with quarantine restrictions and containment measures which was resulted in the decline of consumption.

Consequently, crude oil prices are affected by number of factors such as health emergency (because of COVID-19 pandemic), available technologies for extracting, economic news flow, overall supply, consumer demand, and behaviour of speculators and hedgers on the financial market. Moreover, OPEC takes a role in defining global oil supply which results in the level of prices (Kaufmann et al. 2008).

Faced with unprecedented treats in the markets, individuals are increasingly in need of a safe haven for their investments. The one way how to deal with is to consider the past experience to make decisions for the current affairs. In the

thesis, financial crisis of 2008 and crises caused by COVID-19 pandemic are considered.

Nastou (2003) hypothesizes that commodities have sustainable demand and ability to act as a hedge instrument with the main purpose to reduce or eliminate the portfolio risk. Thus, during the financial turmoil, investors make rebalancing of their portfolios by switching their assets into more liquid alternatives. Gold is considered as one of the most secure options for investing due to the low variability of gold and its ability to sustain wealth during inflation and crises or uncertainties. According to Adrangi et al. (2003) gold was often considered to be a safe haven during periods of economic and political instability.

During the recession of 2008, the gold prices expanded meaningfully. The financial chaos caused by the crash of Lehman Brothers in September 2008 sent gold prices soaring from just over $700 an ounce to as high as $1900 an ounce by October 2011. For three years, stock markets around the globe were volatile, and investors placed a heavy reliance on gold to maintain their capital. After 2011, the price of gold began to fall as stock markets returned to stability.

The strengthening of the trend of oil prices is associated with a changing mechanism of crude oil price formation in a dynamic way. The long-term pattern of crude oil prices is governed by supply and demand.

Started from the 2000s, oil has taken on more significance in the economic and financial realms and has faced sharp fluctuations. Thus, after the oil price drop in 2001-2002, it was followed by a rise until mid-2008.

The surge in crude oil prices in 2006-2007 can be attributed in part to the aggregate demand shock caused by the rapid expansion of the Chinese and developing economies over that period.

Following the 2008 financial crisis, the pricing mechanism in the oil market was broken by external macro uncertainty, described in some literature as a

precautionary demand shock driven by surplus liquidity in the financial market in the aftermath of the mortgage crisis. The rise in the volume of financial transactions adds to the financial strain on the crude oil market.

Furthermore, there have been many studies in the literature that have indicated that severe fluctuations in oil prices are associated with external oil-related events that exacerbate short-term fluctuations in crude oil prices, affecting the balance of oil supply and demand.

There is a bunch of literature which states that crisis related to COVID-19 pandemic looks differently to other crises. This thesis investigates the differences in performance of crude oil and gold markets during crises so that gold could keep demonstrating its outstanding performance as an insurance against risks in the oil market for investors.

There is a vast literature on the factors that determine oil prices. In these studies, researchers usually test what has influenced oil prices or what their impact on macroeconomic indicators was. Hamilton emphasizes that the real price of oil is historically challenging to forecast and is controlled by very different regimes at distinct points in time. Thus, the COVID-19 pandemic can be seen as an external variable that has unpredictable effects on oil price returns.

However, our study differs from other studies on oil price shocks in several ways. First, we assess whether gold can serve as an insurance asset during Covid. Second, we do not just investigate the impact of the COVID-19 shock on the commodity market, but also assess whether there is a pattern of behavior for gold and crude oil during crises, using the examples of the 2008 financial crisis, and the COVID-19 pandemic.

The hypothesis which are tested in the thesis are: (1) there is a change in behaviour of crude oil and gold returns before and during crisis, (2) the COVID-19 shock which is negatively affecting crude oil returns has a positive impact in

gold returns, (3) as any of analysed crisis began gold maintains its ability to acts as a safe haven asset instead of crude oil.

The rest of the paper is structured as follows: section two provides up-to-date outlook to the issue based on the relevant theoretical and empirical evidence; section three describes the methodology to be used; section four contains data description; section five summarizes the estimation results; section six presents conclusions and policy recommendations.

Chapter 2

LITERATURE REVIEW

In this section we will review the following issues: what is the difference between safe asset and safe-haven asset and empirical evidence on gold to be safe-haven; why crude oil shows such volatility in times of crisis and uncertainty; and investigate the literature on the relationships between crude oil and gold during crisis.

The concept of safe-haven asset proposed by Baur, and McDermott (2016) completely differs from the safe asset noted by Gorton at al. (2012). Safe assets are applied when there is a need to hedge or diversify portfolio, however safe-haven assets are used mostly during crisis or market crash. To be a safe-haven asset must be on track to sustain or add value in the event of a market downfall. According to Baur and Lucey (2010), there should no correlation or negative correlation between gains from safe-haven asset and other assets during crisis.

There are a number of researchers who investigated whether gold could serve as a safe-haven tool, however results differ. For instance, Baur and McDermott (2010) stated that gold can act as a safe-haven asset only for the US and main European stock markets and mostly as a hedge against inflation based on the data from emerging and developing countries for 30 years. Investors, which invest their capital into gold, use this asset to protect the wealth in extreme unfavourable market conditions. As a result, this phenomenon causes an increased demand for gold and an overrun in gold prices on a global scale.

Later, Baur and Mack Dermott studied the tendency of gold prices under negative economic conditions and noticed that it is curvilinear. They also hypothesized that negative market conditions have a considerable impact on gold investors.

Additionally, McCown and Zimmerman defined gold as an asset with zero beta, which means no market risk.

However, Hood and Malik (2013) in their research concluded that gold is a hedging asset for the US stock market, but the position as a safe haven is highly questioned relative to the volatility index (VIX). Li and Lucey (2017) stated that precious metals (silver, palladium and platinum) position better as a safe haven tool than gold. They also added that economic and political conditions make significant impact on the choice of safe haven assets.

Empirical evidence is found in the studies of Moore (1990) where it was investigated the relationship between gold prices and the value of stock markets from 1970 to 1988. The negative relationship between gold prices and the value of stock markets was found, suggesting that rising gold prices would typically cause the value of stock markets to depreciate.

These conclusions were also confirmed by Byuksalvarci (2010), who has stated the impacts of seven macroeconomic variables (consumer price index, money market interest rate, gold price, industrial production index, oil price, exchange rate and money supply) on Turkish financial markets. he results of this research revealed that Turkish investors employed gold as an alternative instrument for investing in stocks. When gold prices rose, they put less into stocks and more into gold, given their negative correlation.

Moving further to the commodities, we may say that their prices have a tendency to move in tandem as they are shaped by generic macroeconomic variables including interest rates, exchange rates and inflation. Crude oil and gold are both high-priority strategic commodities that have recently attracted much research coverage. The reason for that in part because of spikes in their prices and increasing economic use. Crude oil is the most traded commodity in the world, and its prices is the most fluctuating among the list of commodities. Gold is

regarded as a leading commodity, since its prices increases appear to cause a concurrent movement in the prices of other precious metals. With the purpose of hedging and diversification, investors often swap oil and gold or combine them to diversify their portfolios.

Apparently, inflation is typically used to explain relationship between crude oil and gold markets. In increase in the crude oil price causes the rise in the general level of prices which in turns pushes gold price to go up. This spike in inflation lead to the higher demand for gold as a mean to hedge against inflation and as a consequence to the increase in prices for gold. For example, Sari at al. (2010) took a look at directional linkages between spot prices of gold, silver, platinum and palladium, oil and exchange rate (USD/Euro). The results showed weak and asymmetric connection between gold and crude oil prices. Hence, gold price returns have absolutely nothing to explain crude oil price returns. However, crude oil price returns explain 1.7% of the gold price returns. In the studies of Zhang et al. (2010) long-term causal and lead-and-lag relationship were addressed between gold and oil. The co-integration between their prices was found meaning that percentage change of crude oil price returns significantly and linearly Granger cause percentage changes in gold price returns.

Since both crude oil and gold are traded in US dollar, the volatility of value of US dollar may cause the prices of these commodities to fluctuate. Zhang and Wei (2010) found high positive correlation between the exchange rate for dollar and crude oil and gold prices. The same with geopolitical events and international political conditions which may impact prices.

However, other studies try to investigate what commodity pushes other to move and who follows. Hammoudeh et al. (2008) have pointed out that the gold price, among other things, causes the price of crude oil to rise. This means that when the global system is subjected to a general stochastic shock, the price of gold

moves first, and the price of oil follows. This inference, though, does not validate the widely held view that the price of oil is the anchor in shaping general inflation. A few other prior studies of Sari et al. (2010) and Hooker (2002) have also revealed that movements in oil prices have an asymmetric effect on macroeconomic variables and the price of gold. Crude oil and gold prices have a marked economic impact on fiscal performance and all sectors of the economy. This impact is reflected explicitly in consumption, industrial production, and investment in all sectors, both real and financial. Volatility in crude oil and gold prices affects stock prices directly, with implications for the capital market. Indirectly, they have consequences for inflation and unemployment which is confirmed by Cebrahim et al. (2014).

Another factor which affects the crude oil price is the geopolitical and weather-related conditions. They may cause the unpredictable shifts in supply and demand which will result in the volatility of crude oil price, that in turn, can create uncertainty in other sectors of economy, as well as instability in bot oil-exporting and oil-importing countries. Derivative markets are also affected in here, since the fair value of a commodity is laid on a contingent claim influenced by the volatility. Stock prices have also dependence on the oil prices. In efficient markets, oil and stock prices are correlated. Increase in the oil price would be associated with the decline in the stock prices of companies which consume oil in their operations. Moreover, changes in oil prices usually adjust with the lagged changes in stock prices. For instance, Huang et al. (1996) investigated that relationship using VAR and found that oil futures return and stock returns moves in the same direction. Masih et al. (2011) states that volatility of oil price defines real stock returns.

Reboredo (2013) assessed the potential of gold to serve as a hedge or safe haven against oil price movement based on the data from January 2000 to September 2011. The result indicated that there is a positive and significant average

relationship between crude oil and gold, which means that gold is not a good hedge against oil price movements. Another conclusion that was reached was the independence of the tails between the two markets, which means that gold can act as an effective hedge on extreme fluctuations in oil prices.

Financial Crisis 2008 is deliberated as one of the most severe financial crises since the Great Depression. Aruga et al. (2020) investigated the linkages between oil, gold and platinum markets on the example of global financial crisis of 2008. The authors have found that the gold market has remained decoupled from the oil market since the 2008 financial crisis, which means that gold is independent of the crude oil market.

Zhang and Hamori (2021) analysed crude oil and stock markets during global pandemic and provided evidence from the US, Japan and Germany. Using the time-domain approach and the method based on frequency dynamics they found that return spillover between these two markets occurs mostly in the short run perspective. However, volatility spillover takes place in the long run. COVID-19 created the unexpected level of risk for the market which is by volatility exceeded the situation in 2008 global financial crisis. Albulescu (2020) studied the effects of the COVID-19 pandemic on crude oil prices, factoring in the impact of financial turmoil and uncertainty in U.S. economic policy. The author concluded that reports of new COVID-19 infections on a daily basis would have a negligible negative impact on crude oil prices.

Gil-Alana and Monge (2020) explored the influence of COVID-19 on WTI crude oil prices applying long-run memory methods. They revealed that the oil price series are mean reversible, which means that the shock will be transient, although with a long-run effect.

Based on that literature, we may conclude that performance of safe asset varies depending on the exact asset class or market being examined; safe haven ability

might fluctuate with time or might be influenced by basic features of market turbulence. The question, which is raised, whether the same asset could be taken as safe haven in any crisis.

Chapter 3

METHODOLOGY

In this thesis we aim to identify whether there are any differences in performance of crude oil and gold markets during crises so that gold could keep demonstrating its outstanding performance as an insurance against risks in the oil market for investors. So, we will describe the nature of gold price with key determinants such as NASDAQ Composite Index (NASDAQ), crude oil price, interest rate and consumer price index by applying ARDL analysis on daily time series for three periods, from 2007 to 2010 and from 2019 to 2020.

The empirical model is given by equation (1):

$$\text{GoldPrice} = \int(\text{NASDAQ}, \text{InterestRate}, \text{CPI}, \text{CrudeOil}), \quad (1)$$

where:

GoldPrice - gold price in US dollar,

NASDAQ – Nasdaq Composite stock market index,

InterestRate – interest rate in the United States,

CPI – consumer price index,

CrudeOil – West Texas Intermediate futures crude oil price.

The methodology which we applied in the thesis is autoregressive distributive lag (ARDL) co-integration approach proposed by Peseran and Shin (1998). It is used to identify the existence of a long-term relationships with the lagged levels if the variables. The main advantage of this technique is that it can be used despite of the stationarity properties of the selected variables and allows to test the long-run relationships between them. Our purpose is to identify the dependent variable, which refers to endogenous, and the independent variables, which refer to

exogeneous. In general, if the association between the selected variables is long term, the ARDL analysis generates an error correction model (ECM) equation for each of the variables, which delivers information via the estimated error correction term about the rate at which the dependent variable returns to equilibrium after a shock.

The ARDL model specifications of the functional relationship between gold price, NASDDAQ composite index, interest rate, CPI, WTI crude oil price can be estimated using proposed equation (2):

$$\begin{aligned}\mathrm{DGoldPrice}_t &= \alpha_0 + \sum_{i=1}^{k} ß_1\, \mathrm{DGoldPrice}_{t-1} + \sum_{i=1}^{k} ß_2\, \mathrm{DNASDAQ}_{t-1} + \\ &\sum_{i=1}^{k} ß_3\, \mathrm{DInterestRate}_{t-1} + \sum_{i=1}^{k} ß_4\, \mathrm{DCPI}_{t-1} + \sum_{i=1}^{k} ß_5\, \mathrm{DCrudeOil}_{t-1} + \\ &b_1 \mathrm{LGoldPrice}_{t-1} + b_2 \mathrm{LNASDAQ} + b_3 \mathrm{LInterestRate}_{t-1} + b_4 \mathrm{LCPI}_{t-1} + \\ &b_5 \mathrm{LCrudeOil}_{t-1} + u_t, \end{aligned} \quad (2)$$

where k = lag order.

According to the ARDL-bound testing procedure, we could take into consideration variables of integration of order 0 and 1 together. We test the null hypothesis of the non-existence of a long-run relationship. It is indicated as $H_{\mathrm{LGoldPrice}}$ (LGoldPrice|LNASDAQ, LInterestRate, LCPI, LCrudeOil) and other components are indicated in the following way (Equations 3-6):

$$H_{\mathrm{LNASDAQ}}\ (\mathrm{LNASDAQ} \mid \mathrm{LGolpPrice, LInsterestRate, LCPI, LCrudeOil}) \quad (3)$$

$$H_{\mathrm{InterestRate}}\ (\mathrm{LInterestRate} \mid \mathrm{LNASDAQ, LGoldPrice, LCPI, LCrudeOil}) \quad (4)$$

$$H_{\mathrm{LCPI}}\ (\mathrm{LCPI} \mid \mathrm{LGoldPrice, LNASDAQ, LInterestRate, LCrudeOil}) \quad (5)$$

$$H_{\mathrm{LCrudeOil}}\ (\mathrm{LCrudeOil} \mid \mathrm{LGoldPrice, LNASDAQ, LInterestRate, LCPI}) \quad (6)$$

These hypotheses are tested against alternative hypothesis which will denote the existence of co-integration between variables (Equation 7):

$$H_0 = ß_1 = ß_2 = ß_3 = ß_4 = ß_5 = 0 \qquad (7)$$

Against the hypothesis (Equation 8):

$$H_1 = ß_1 \neq ß_2 \neq ß_3 \neq ß_4 \neq ß_5 \neq 0 \qquad (8)$$

Using the Wald test F-statistics was calculated and compared with critical values provided by Pesaran et al. (2001). The rule is the following: if the calculated F-statistics is less than the lower-bound critical values, then we fail to reject the null-hypothesis which indicates the non-existence of a long-run relationship. Furthermore, is the F-statistics is located between lower- and upper-bound critical values, then the result is inconclusive; however, if the calculated F-statistics is above the upper-bound critical values, then we reject the null hypothesis of non-existence of a long-run relationship.

After analysing long-run relationship between variables we turn to the selection of the appropriate number of lag length. For that purpose, we use standard criteria – Schwarz Bayesian criterion (SBC) or Akaike Information (AIC). Once we have these tests, we can forecast the long-run and short-run coefficients. The long-run form ARDL is presented in equation (9):

$$\mathrm{LGoldPrice_t} = \alpha_0 + \sum_{i=i}^{k} ß_1\, \mathrm{LGoldPrice_{t-i}} + \sum_{i=1}^{k} ß_2\, \mathrm{LNASDAQ_{t-i}} + \sum_{i=1}^{k} ß_3\, \mathrm{LInterestRate_{t-i}} + \sum_{i=1}^{k} ß_4\, \mathrm{LCPI_{t-i}} + \sum_{i=1}^{k} ß_5\, \mathrm{LCrudeOil_{t-i}} + u_t. \quad (9)$$

For the short-run ARDL model we applied error-correction term (ECT) to show the short run tendency. The equation (10) is shown below:

$$\mathrm{DGoldPrice_t} = \alpha_0 + \sum_{i=1}^{k} ß_1\, \mathrm{DGoldPrice_{t-1}} + \sum_{i=1}^{k} ß_2\, \mathrm{DNASDAQ_{t-1}} + \sum_{i=1}^{k} ß_3\, \mathrm{DInterestRate_{t-1}} + \sum_{i=1}^{k} ß_4\, \mathrm{DCPI_{t-1}} + \sum_{i=1}^{k} ß_5\, \mathrm{DCrudeOil_{t-1}} + ß_6 \mathrm{ECT_{t-1}}, \quad (10)$$

where, ECT = lagged error-correction term.

Then, we test the null hypothesis H0 that there is no long-run relationship against the alternative hypothesis H1 that there is long-run relationship (Equations 11-12):

$$H_0 = ß_1 = ß_2 = ß_3 = ß_4 = ß_5 = 0 \quad (11)$$

$$H_1 = ß_1 \neq ß_2 \neq ß_3 \neq ß_4 \neq ß_5 \neq 0 \quad (12)$$

To make our variables stationary in variance, we performed logarithmic transformation with them. We then proceeded to an empirical test, identifying the stationarity of all the variables in our examination. To test for stationary, Augmented Dickey-Fuller (ADF) test was performed. Stationarity test is required for later co-integration proofing. Optimally, our parameters should be I(1), i.e., they are only stationary after the first difference. For each variable used, a differenced

form is produced by taking the difference of their respective logarithms (e.g., DGoldPrice = LGoldPrice – $LGoldPrice_{t-1}$). Before proceeding with test for co-integration, we determined the order of vector autoregressive (VAR), meaning quantity of lags which is necessary for usage.

Chapter 4

DATA

For our analysis we estimate the long-run relationship between gold and selected variables to depict whether gold could be used as safe-haven in times of market turbulence. For the sake of turbulence, we used two global crisis –financial crisis of 2008-2009, and crisis of 2020 caused by global COVID-19 pandemic. The detailed information with timeline and sources is presented in Table 1. To estimate the long-run relationship we use the time-series dataset of price for gold as dependent variable. Price for gold is valued by London Bullion Market Association (LBMA) fixing price in the US dollars per troy ounce.

As control variable crude oil prices for West Texas Intermediate. The data is collected from US Federal Reserve Bank of St. Louis economic database in daily format.

As independent variables the following variables were taken Nasdaq Composite Index (NASDAQ), interest rate and CPI. All of the data is presented in levels with a base year 2003.

NASDAQ was takes as economic indicator to capture the effects of the US overall economic performance. The daily data for this indicator is provided by US Federal Reserve Bank of St. Louis economic database in daily format.

As for the interest rate we took effective federal funds rate for the United States provided by US Federal Reserve Bank of St. Louis economic database in daily format. The federal funds rate is the interest rate at that depository institutions bargain with each other overnight federal funds. The effective federal funds rate is market driven, but it is impacted by the Federal Reserve via open market operations to attain the target level of the federal funds rate.

Table 1.Timeframes of the selected crisis used for the analysis

Crisis	Date	Specific event	Source
Financial crisis	Fin crisis I February 7, 2007 – June 29, 2007	The giant Freddie Mac announced it will no longer buy riskier subprime mortgages. In April New Century Financial Corp. filed for bankruptcy.	Federal Reserve Bank of St. Louis
	Fin crisis II August 9, 2007 – February 27, 2009	BNP Paribas stopped payments, or funds demanded by investors, on three investment funds. In January 2008 the FED decreased the federal funds rate to 3.5%. On September 15, 2008 Lehman Brothers investment bank files for the largest bankruptcy in the history. On November 25, 2008 FED announced the first cycle if quantitative easing. In September 2008 Ireland became one of the first countries which started recession.	
	Fin crisis III March 5, 2009 – May 10, 2010	FED and number of other countries started to cut interest rate to zero. US started to recover.	
COVID-19 crisis	COVID-19 I October 31, 2019 – February 10, 2020	Wuhan Municipal Health Commission stated a cluster of cases of pneumonia in Wuhan. Number of resolutions from WHO. Infection of people outside China.	Carvalho et al. (2021)
	COVID-19 II February 11, 2020 - March 16, 2020	On January 20, 2020, it was first confirmed case of COVID-19 in the US. On March 11, 2020 WHO declared a COVID-19 a pandemic.	
	COVID-19 III March 24, 2020 – June 30, 2020	S&P500 started to show signs of recovery. On June 30, 2020, the EU said it would open borders.	

Consumer Price Index is represented by the 10-year Breakeven Inflation rate which is a measure of expected inflation. It is calculated on the basis of 110-year Treasury Constant Maturity Securities and 10-year Treasury Inflation-Indexed Constant Maturity Securities. This parameter is important for our analysis because it reflects the average market expectation for inflation over the next 10 years. The daily data is provided by US Federal Reserve Bank of St. Louis economic database.

Figure 1 represents the dynamics of crude oil, gold and Nasdaq stock market index dynamics for the recent two decades. As seen in Figure 1, crude oil exhibited a downward trend during the market crisis, while old and Nasdaq represents some resilience to the market shocks.

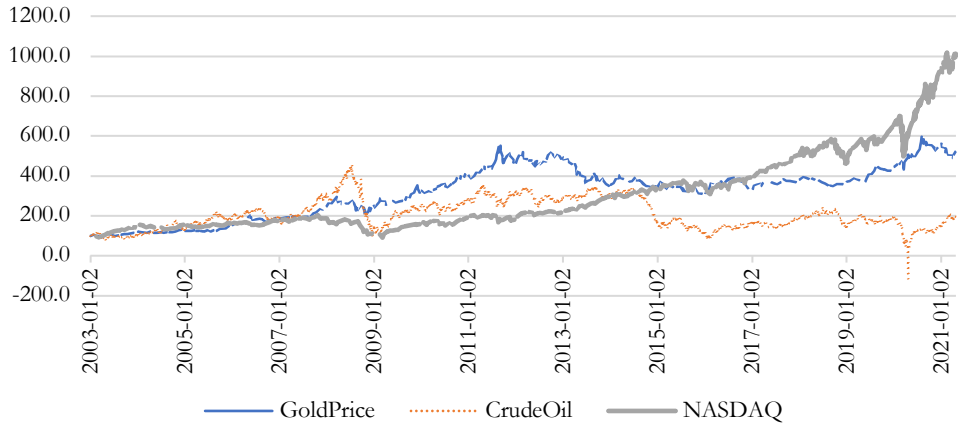

Figure 1. Gold, Crude Oil and Nasdaq index dynamics (2003 = 100)
Source: US Federal Reserve Bank of St. Louis, own calculations

Figure 2 represents the behavior of 10-year Inflation Expectations and Federal Funds rate. It could be seen that before financial crisis the inflation expectation raised significantly compared to the base year of 2003. Then during economic downturn inflation expectation felled to the level even less than in 2003. The same

picture is observed before COVID-19 crisis. Inflation started to rise in 2016 till the COVID-19 outbreak. During economic crisis inflation expectations decreased before the economic recovery starts.

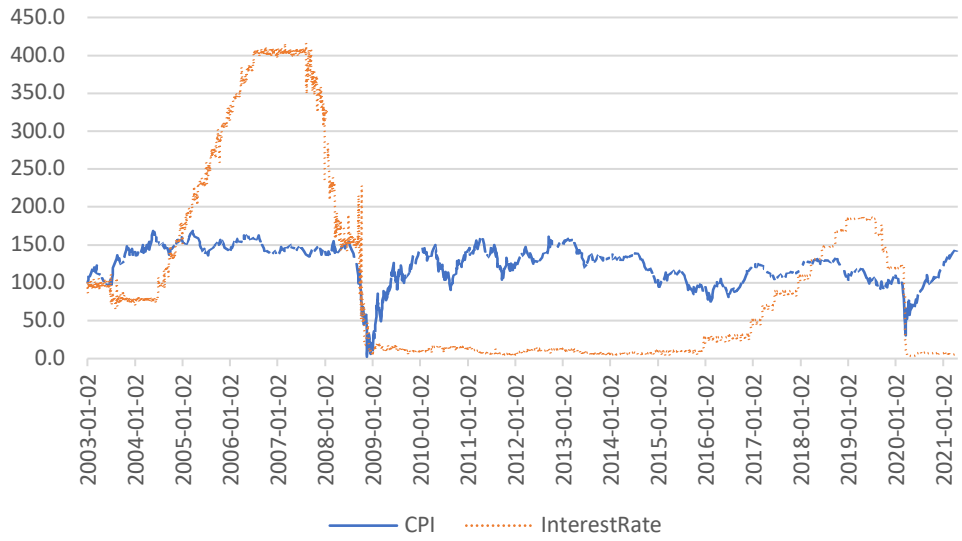

Figure 2. CPI and Interest Rate dynamics (2003 = 100)

Source: US Federal Reserve Bank of St. Louis, own calculations

Table 2 represents the descriptive statistics of variables used in the thesis. The descriptive statistics is shown separately for the periods analyzed. For the period from 2007-2020, among three financial market indicators (gold, crude oil and Nasdaq stock market index), Nasdaq stock market index has shown the highest level of volatility. Minimum negative value of crude oil is attributed to the COVID-19 crisis when prices for West Texas Intermediate reached its all-time minimum. The detailed descriptive statistics for each period analysed is in Appendix A and B.

The further discussion of stationarity of variables as well as confirmation of level of their integration are provided in the next chapter.

Table 2. Descriptive statistics of explanatory variables: all periods

Variables	Number of observations	Mean	Standard Deviation	Min	Max
All periods (February 7, 2007 – June 30, 2020)					
Gold Price	4,590	320.0822	127.104	93.0482	601.2653
Crude Oil		207.0687	74.8660	-115.6709	454.5199
CPI		124.119	25.0094	2.4390	168.2927
Interest Rate		101.9685	122.6692	3.0769	416.1538
NASDAQ		301.2655	196.1535	91.6084	1017.834
Financial crisis (February 7, 2007 – May 9, 2010)					
Gold Price	815	256.7577	43.3776	185.2094	352.676
Crude Oil		246.9433	75.1765	94.7137	454.5199
CPI		120.428	35.6408	2.4390	156.7073
Interest Rate		157.3058	158.9037	3.8461	416.1538
NASDAQ		158.9848	27.7091	91.6048	206.457
Covid -19 crisis (October 31, 2019 – June 30, 2020)					
Gold Price	167	466.5492	29.1161	422.3531	515.2996
Crude Oil		131.2675	51.9943	-115.6709	197.9043
CPI		84.7891	18.9527	30.4878	109.7561
Interest Rate		66.2597	56.1060	3.0769	123.0769
NASDAQ		639.7608	52.1990	495.4090	731.5859

Chapter 5

ESTIMATION RESULTS

5.1. Unit root test

We conducted the Augmented Dickey-Fuller (ADF) test to confirm the level of integration. The ADF test was performed for both level and differenced forms of the variables. The stationary series has a mean value, finite variance, with shocks that are transient and autocorrelation coefficients that disappear as the number of lags continues to grow, whereas the nonstationary series has infinite variance, shocks that are constant, and its autocorrelations aspire to unity.

As an analogy to the Dickey-Fuller stationarity test, the Phillips-Perron test for the unit root of a variable was conducted. The null hypothesis is that the variable holds a unit root, and the alternative hypothesis is that the variable was generated by a stationary process. The results of unit tests are shown in the Table 3.

Table 3. Unit root test

	ADF test			Phillips-Perron test		
Variable	t-statistics	CV	Result	t-statistics	CV	Result
Logarithm transformed variables						
LGoldPrice	-1.689	-3.430	NS	-1.687	-3.430	NS
LCrudeOil	-5.926	-3.430	S	-5.828	-3.430	S
LCPI	-2.586	-3.430	NS	-3.053	-3.430	NS
LInterestRate	0.659	-3.430	NS	1.004	-3.430	NS
LNASDAQ	-0.101	-3.430	NS	-0.018	-3.430	NS
Differenced transformed variables						
DGoldPrice	-49.422	-3.430	S	-49.404	-3.430	S
DCrudeOil	-56.417	-3.430	S	-55.973	-3.430	S
DCPI	-47.444	-3.430	S	-47.531	-3.430	S
DInterestRate	-50.300	-3.430	S	-50.523	-3.430	S
DNASDAQ	-57.134	-3.430	S	-57.132	-3.430	S

Note: NS – not stationary variable, S – stationary variable

The tests show that variables of our interest mostly stationary in logarithm, except of CrudeOil. The results of both tests are consistent with each other and depict similar results. Since, our variables are of different order of integration, it is appropriate to apply ARDL approach to test the long-run relationship between all of the variables. Moreover, none of the tests found that our variables are of order of integration I(2), confirming that ARDL technology could be used.

It is necessary to determine the order (number of lags) of the vector autoregressive before providing the test for co-integration. We provide test for different time periods of our analysis (Table 4). For most of series, applicable number of lags is one. This can be explained as the intrinsic property of the time series data of our research. This restriction can be addressed by the ARDL method, which defines a particular order of lags for each variable in our study.

Table 4. VAR lag-order selection

Time period	Selection criteria	
	AIC	SBIC
Fin crisis I	3	1
Fin crisis II	3	1
Fin crisis III	3	1
COVID-19 I	3	3
COVID-19 II	3	3
COVID-19 III	3	3

5.2. Testing for cointegration

We apply ARDL model as our variables are of order of integration I(0) and I(1) for each period of our analysis. We provide the maximum number of lags based on

the VAR lag-order selection criteria and ARDL technique automatically select the number applicable. Tables 5-6 summarize the obtained results.

As for the financial crisis, in the early stage, 1% increase in gold prices leads to the decrease of 0.06% of price for crude oil on average. 1% increase in gold price leads to the 0.14% increase in inflation expectations. During the second stage, we observed that 1% increase in gold prices leads on average to the 0.11% increase in crude oil prices and 0.13% increase on Nasdaq index. During the last stage, increase in gold prices associated even with higher increase in crude oil prices, however, decrease in CPI by 0.02%.

Table 5. ARDL results for financial crisis analysis

	Fin Crisis I	Fin Crisis II	Fin Crisis III
ARDL specification	(1,0,0,0,0)	(1,1,1,0,1)	(1,1,0,0,0)
L1 (lnGoldPrice)	0.7959***	0.9887***	0.9889***
	(0.0551)	(0.0124)	(0.0161)
lnCrudeOIl	-0.0633**	0.1108***	0.1887***
	(0.0297)	(0.0292)	(0.0334)
L1 (lnCrudeOil)		-0.1107***	-0.1547***
		(0.0289)	(0.0310)
lnCPI	0.1393*	0.0146**	-0.0201**
	(0.0716)	(0.0059)	(0.0098)
L1 (lnCPI)		-0.0209***	
		(.0062)	
lnInterestRate	-0.2504	0.0025	0.0021
	(0.1635)	(0.0024)	(0.0035)
lnNasdaq	0.0595	-0.1374***	-0.0044
	(0.0456)	(0.0451)	(0.0168)
L1 (lnNasdaq)		0.1366***	
		(0.0458)	
Constant	1.9080*	0.0817	-0.0068
	(1.1355)	(0.0922)	(0.0640)
Observations	78	293	224
R2	0.8050	0.9750	0.9868
Note:		**p<0.1, **p<0.05, ***p<0.01*	

As for the COVID-19 crisis, the preliminary stage indicates the increase of interest rate by 0.11% and 0.34% in Nasdaq index one day before the increase in gold prices. When the pandemic actually has started globally, the greater negative response is observed for interest rates. And during the period till June 2020 the negative impact of 0.01% is found for crude oil, increase in inflation expectation is present, even further decrease in interest rates, and rebounding of Nasdaq index.

Table 6. ARDL results for COVID-19 crisis analysis

	COVID-19 I	COVID-19 II	COVID-19 III
ARDL lags	(1,0,0,1,2)	(1,0,0,0,0)	(1,0,1,2,0)
L1 (lnGoldPrice)	0.8961***	0.8809***	0.5147***
	(0.0537)	(0.1757)	(0.1298)
lnCrudeOIl	-0.0137	0.1189	-0.0103*
	(0.0388)	(0.1388)	(0.0084)
lnCPI	-0.0472	-0.0425	-0.0467
	(0.0454)	(0.1046)	(0.0463)
L1 (lnCPI)			0.1213**
			(0.0463
lnInterestRate	-0.0389	-0.0690**	-0.0581**
	(0.1350)	(0.0293)	(0.0215)
L1 (lnInterestRate)	0.1101***		-0.0150
	(0.0344)		(0.0265)
L2 (lnInterestRate)			0.0522**
			(0.0227)
lnNasdaq	-0.0837	0.0629	0.1303**
	(0.1469)	(0.1098)	(0.0532)
L1 (lnNasdaq)	-0.1197		
	(0.2294)		
L2 (lnNasdaq)	0.3401*		
	(0.1672)		
Constant	-0.4442	0.2476	1.9284***
	(0.7790)	(1.4415)	(0.5952)
Observations	33	19	37
R^2	0.9859	0.7781	0.9173
Note:		**p<0.1, **p<0.05, ***p<0.01*	

Engle-Granger tests for cointegration to find short-run and long-run relationships were conducted. The existence of a cointegration argument assumes that the association between the variables is not contrived, i.e., that there is a theoretical interaction between the variables and that they are in long-run equilibrium.

As shown in Table 7, the critical value is below the t-statistic values meaning that we can reject the null hypothesis that residuals are not stationary. Statistically speaking, such results depicts that the chosen variables would end with the stationary error term. And the stationary error term means that there exists cointegration between variables. However, if the Engle-Granger test does not show the cointegration between variables it could indicate that variables are fractionally cointegrated. In such a way, we found that there exists short-run relationships between variables.

Table 7. Engle-Granger test for cointegration

	Short-run		Long-run	
Time period	t-statistics	1% critical value	t-statistics	1% critical value
Fin crisis I	-6.167	-5.249	-3.656	-5.188
Fin crisis II	-11.866	-5.033	-2.030	-5.016
Fin crisis III	-14.185	-5.057	-2.175	-5.034
COVID-19 I	-6.175	-5.466	-2.320	-5.316
COVID-19 II	-2.578	-6.313	-1.645	-5.995
COVID-19 III	-7.508	-5.404	-3.721	-5.305

Then, the Wald test to calculate F-statistics for long-run (logarithmic transformed variables) was performed (Table 8). The results indicate that we can reject the H0 of the non-existence of a co-integrating long-run relationship, meanings that long-

run relationship between variables is actually present. Proving a long-term relationship excludes the possibility of any false connection between the variables.

Table 8. Wald test

	F statistics	p-value
Fin crisis I	2.17	0.0807
Fin crisis II	7.25	0.0000
Fin crisis III	8.40	0.0000
COVID-19 I	2.78	0.0404
COVID-19 II	3.11	0.0534
COVID-19 III	2.74	0.0483

Further, we need to find which of the variables are endogenous and which are exogeneous. We conduct an ARDL test to estimate long-term coefficients, as well as an ECM to confirm the endogeneity and exogeneity of the variables.

5.3. Bounds testing

Table 9 provides information on variables where the cointegration between variables were found. We found that using GoldPrice as dependent variables does not prove significant cointegration with other variables. Nevertheless, the proof of the long-run relationship excludes the possibility of any contrived relationship among the variables. To put it another way, a theoretical relationship exists for the variables. The procedure was replicated for the other variables, and the outcome indicated that the interest rate, crude oil prices and CPI show strong support for a long-run relationship with the explanatory variables.

The rule is the following: if the calculated F-statistics is less than the lower-bound critical values, then we fail to reject the null-hypothesis which indicates the non-existence of a long-run relationship. Furthermore, if the F-statistics is located between lower- and upper-bound critical values, then the result is inconclusive; however, if the calculated F-statistics is above the upper-bound critical values, then we reject the null hypothesis of non-existence of a long-run relationship.

Table 9. Estimated long-run coefficients

	Variable	F-statistics	Lower bound	Upper bound	CV (%)
Fin crisis I	InterestRate	8.809	3.018	4.220	5
Fin crisis II	CrudeOil	5.745	2.893	4.041	5
	InterestRate	5.270	2.890	4.042	5
Fin crisis III	CrudeOil	7.745	2.902	4.058	5
COVID-19 I	CrudeOil	7.591	3.333	4.779	5
	InterestRate	116.440	3.336	4.764	5
COVID-19 II	CrudeOil	5.265	3.074	4.493	10
COVID-19 III	CPI	5.660	3.259	4.659	5
	InterestRate	8.770	3.247	4.712	5
	CrudeOil	4.004	2.698	3.885	10

5.4. Error correction model of ARDL

Let us investigate the most important period of these two crises (Fin crisis I, Fin crisis II, COVID-19 II, COVID-19 III) when the outbreak to the economy was made. From the previous testing we found that interest rate, crude oil and CPI in different periods point to convincing support for a long-term connection with determinants. However, for Fin crisis I, Interest rate implies slow speed of

adjustment to equilibrium after shock. For the second period of financial crisis there is evidence that Crude oil price, CPI and Nasdaq index is highly responsive in the short run (Table 10).

Table 10. ECM of ARDL (Financial crisis)

	Fin Crisis I	Fin Crisis II	Fin Crisis III
ARDL lags	(1,0,0,0,0)	(1,1,1,0,1)	(1,1,0,0,0)
ADJ			
L1 (lnGoldPrice)	-0.2040***	-0.0112	-0.0110
	(0.0551)	(0.0124)	(0.0161)
LR			
lnCrudeOil	-0.3106**	0.0148	3.0636
	(0.1471)	(0.4289)	(4.6133)
lnCPI	0.6829**	-0.5621	-1.8144
	(0.3376)	(0.7648)	(2.8556)
lnInterestRate	-1.2274	0.2290	0.1896
	(0.8253)	(0.3699)	(0.4639)
lnNasdaq	0.2916	-0.0683	-0.4020
	(0.2208)	(1.2432)	(1.8400)
SR			
D1 (lnCrudeOil)		0.1107***	0.1547***
		(0.0289)	(0.0310)
D1 (lnCPI)		0.0209***	
		(0.0062)	
D1 (lnNasdaq)		-0.1366***	
		(0.0458)	
Constant	1.9080*	0.0817	-0.0068
	(1.1355)	(0.0922)	(0.0640)
Observations	78	293	224
R^2	0.1883	0.1144	0.1500
Note:		**p<0.1, **p<0.05, ***p<0.01*	

The error correction coefficients estimated for the COVID-19 III variables are significant at level from 90% to 99%, has the correct relationship (correct sign) according to the theory and suggests the presence of a medium- to long-term

tailoring of the equilibrium after a shock. Moreover, the effect of CPI and interest rate is present in the short run.

Table 11. ECM of ARDL (COVID-19 crisis)

	COVID-19 I	COVID-19 II	COVID-19 III
ARDL lags	(1,0,0,1,2)	(1,0,0,0,0)	(1,1,0,0,0)
ADJ			
L1 (lnGoldPrice)	-0.1038*	-0.1190	0.4852***
	(0.0537)	(1.5980)	(0.1298)
LR			
lnCrudeOil	0.1320	0.9989	-0.0212*
	(0.3986)	(1.5980)	(0.0171)
lnCPI	-0.4549	-0.3574	0.1539*
	(0.5145)	(0.9664)	(0.0816)
lnInterestRate	0.6864	-0.5799	-0.0432***
	(1.2870)	(0.8262)	(0.0155)
lnNasdaq	1.3168**	0.5288	0.2685***
	(0.5196)	(1.5061)	(0.0745)
SR			
D1 (lnCPI)			-0.1213**
			(0.0463)
D1 (lnInterestRate)	-0.1101***		-0.0372*
	(0.0344)		(0.0193)
LD (lnInterestRate)			-0.0522**
			(0.0227)
D1 (lnNasdaq)	-0.2204		
	(0.1464)		
LD (lnNasdaq)	-0.3401*		
	(0.1672)		
Constant	0.4442	0.2476	1.9284***
	(0.7790)	(1.4415)	(0.5952)
Observations	33	19	37
R^2	0.4966	0.5476	0.4792
Note:		**p<0.1, **p<0.05, ***p<0.01*	

In addition to this, we can claim that the Vector Error Correction Model (VECM) provides a solid representation of the short- and long-term inter-variable

relationships; nearly half of our variables are endogenous, while remaining variables are independent in the model. Moreover, we found that the nature of gold price formation mechanism is similar based on two crises analyzed.

5.4. Post estimation results

To provide evidence of correctness of our results we performed the number of post estimation test.

The results of the tests are presented in the Table 12-13. Our models satisfy the requirements of no autocorrelation and constant variance. One of the tests for autocorrelation implies possible autocorrelation of the model however it could be result of stock market nature when stock market prices defined based on the lagged terms of the variable.

Table 12. Post estimation results (Financial crisis)

Test	Fin crisis I	Fin crisis II	Fin crisis III
Durbin-Watson	1.56	1.34	1.69
Decision	No autocorr.	No autocorr.	No autocorr.
Breusch-Godfrey	0.2852	0.0632	0.0839
Decision	No autocorr.	No autocorr.	No autocorr.
Breusch-Pagan	0.52	1.23	0.38
Decision	No heterrosced.	No heterrosced.	No heterrosced.

Table 13. Post estimation results (Financial crisis)

Test	COVID-19 I	COVID-19 II	COVID-19 III
Durbin-Watson	1.95	2.3	1.48
Decision	No autocorr.	No autocorr.	No autocorr.
Breusch-Godfrey	0.0205	0.1129	0.0001
Decision	autocorr.	No autocorr.	autocorr.
Breusch-Pagan	4.77	6.79	0.17
Decision	No heterrosced.	No heterrosced.	No heterrosced.

Breusch-Godfrey test for autocorrelation was proposed. The decision rule which was applied is to reject the null hypothesis of no serial correlation at up to 3 lags is the p-value of the regressors is less that the level of significance of 5%.

Another test (Durbin-Watson statistic) for autocorrelation in the residuals was made. A value of test usually lies from 0 to 4, indicating positive autocorrelation from 0 to 2 and negative – from 2 to 4. A value from 1.5 to 2.5 is considered as norm.

Breusch-Pagan / Cook-Weisberg test for heteroscedasticity was conducted. The null hypothesis of the test is that there is constant variance. The alternative hypothesis states that the error variance increase (or decrease) as the predicted values of Y increase. A large chi-square would indicate that heteroscedasticity was present.

Chapter 6

CONCLUSIONS AND POLICY RECOMENDATIONS

In this thesis we analyzed the relationship between gold prices and crude oil prices, inflation expectations, interest rate and Nasdaq index. Goal of this research is to find the evidence that the gold has the similar nature of behavior during crises. For that purpose, we investigated the behavior of this commodity during COVID-19 and financial crisis of 2008 as the two examples of the outbreak of the economy.

Our results show that gold prices have long-run relationship with crude oil prices, inflation expectations and interest rates. Moreover, it was depicted that interest rate and inflation expectation have short term relationship with dependent variable during COVID-19 crisis. Crude oil has short-term relationship with gold prices during the financial crisis of 2008.

Gold prices negatively related to crude oil prices, which supports the role of gold as a hedge. Gold serves as a good hedge against inflation as it moves in the same direction.

Moreover, we found that the nature of gold price movements is similar based on two crises analyzed.

Further research in this area can be developed in a number of ways. In the methodological terms, additional alternative methods, such as copula, artificial neural networks, Fourier transform, and wavelet analysis, could be used to evaluate the potential for improving forecasting ability. Other research approaches, such as behavioral finance models, can be probed using investor personal choice microdata to examine their impact on gold prices. Research can compare household and corporate decisions to own gold to assess consumer and investment motives for buying gold.

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APPENDIX A

Descriptive statistics: financial crisis

Variables	Number of observations	Mean	Standard Deviation	Min	Max
Financial crisis (February 7, 2007 – June 29, 2007)					
Gold Price	100	193.2396	3.7028	185.2094	201.1053
Crude Oil		197.5249	10.4282	176.4467	220.4254
CPI		146.0155	2.5588	141.4634	151.8293
Interest Rate		404.2041	2.4020	399.2308	416.1538
NASDAQ		181.1934	5.5055	169.0205	189.6783
Financial crisis (August 9, 2007 – February 27, 2009)					
Gold Price	388	245.6766	24.2913	191.2449	294.1390
Crude Oil		281.9001	91.6850	94.7137	454.5199
CPI		115.4058	44.7574	2.4390	156.7073
Interest Rate		188.5327	125.1057	6.1538	416.1538
NASDAQ		160.6440	30.7384	95.0370	206.4570
Financial crisis (March 5, 2009 – May 10, 2010)					
Gold Price	294	298.7714	27.5535	253.1268	352.6760
Crude Oil		219.9696	33.8607	132.8120	270.6913
CPI		116.8610	22.6743	49.3902	149.3902
Interest Rate		11.8585	2.5928	3.8461	19.2307
NASDAQ		147.1129	20.5269	91.6084	182.7021

APPENDIX B

Descriptive statistics: COVID-19 crisis

Variables	Number of observations	Mean	Standard Deviation	Min	Max
Covid -19 crisis (October 31, 2019 – February 10, 2020)					
Gold Price	67	438.6562	13.2619	422.3531	460.7912
Crude Oil		179.9168	10.2384	155.1142	197.9043
CPI		103.0124	3.5473	93.9024	109.7561
Interest Rate		119.6096	1.0404	118.4615	123.0769
NASDAQ		641.6469	25.8382	598.7911	691.205
COVID-19 crisis (February 11, 2020 – March 16, 2020)					
Gold Price	24	470.9885	11.2969	454.5666	489.7179
Crude Oil		142.6228	24.2586	97.1223	168.1889
CPI		86.3732	16.4044	54.8780	101.8293
Interest Rate		108.6622	18.3903	83.8461	122.3077
NASDAQ		644.4875	53.0059	520.0420	708.8984
COVID-19 crisis (March 24, 2020 – June 30, 2020)					
Gold Price	69	495.2081	13.1663	458.5660	515.2996
Crude Oil		84.7706	37.4576	-115.6709	126.9941
CPI		70.1307	7.0928	53.0487	84.1463
Interest Rate		4.7802	1.4219	3.0769	9.2307
NASDAQ		647.0741	58.3388	531.5075	731.5859