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Testing the Weak Form of Efficient Market Hypothesis in Period of the Global Pandemic of 2020 and the Russian Invasion in 2022: Empirical Evidence from XAU, XAG and XPT

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Abstract: *This study intends to determine if the events of 2020 and 2022 have had an impact on the efficiency of the commodities markets, in particular the spot prices of gold (XAU), silver (XAG), and platinum (XPT), between September 18th, 2017, and September 15th, 2022. The findings of the Rankings and Signals test demonstrate that, during the calm time, the gold, silver, and platinum markets do not reject the random walk hypothesis, which means that spot prices are independent and identically distributed (i.i.d.), consequently their movements are assumed to be random. Contrarily, the random walk hypothesis is rejected during the Stress period in all commodity markets, with variance ratios below unity, suggesting that returns show significant autocorrelation. To support this, the findings of the exponent Detrended Fluctuation Analysis (DFA) reveal that silver (XAG) had an antipersistent short memory (α < 0,5), during the Calm period, transitioning to a persistent movement (α > 0,5) during the time of the crisis. While the worldwide financial markets were stable, platinum (XPT) was in a state of equilibrium. This state changed to persistent with the succession of events starting in 2020 (α >0,5). In turn, gold (XAU) reduced its antipersistence (α <0,5) throughout the period of stress in international markets. In conclusion, there is evidence of some dependency in the time series, but this dependence does not appear to be easily exploitable by investors. These findings have significant implications for gold, silver, and platinum's roles as investment assets.*

1. INTRODUCTION

One of the most significant economic and financial theories tested over the last century is the efficient market hypothesis (EMH). Due to numerous contradictory evidence, also known as anomalies against HME, some researchers have questioned whether the HME hypothesis is valid so many theories have been developed to explain some of the anomalies (Fama, 1965, 1970, 1991).

The gold, silver and platinum markets are precious metal markets that have evolved into potential investment assets. From the perspective of an investor, it is critical to understand that the spot prices of these precious metals represent the relevant information set at each moment in time. This paper examines a sequence of price changes for each metal to see whether these

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markets are efficient, that is, whether the random walk and martingale hypothesis are verified in times of stress in international financial markets (Dias & Carvalho, 2020, 2021; Dias et al., 2021; Teixeira et al., 2022).

In recent decades, we learned that speculation is a necessary element of the price discovery process and that efforts to eliminate such speculation reduce informational efficiency in international financial markets dramatically. In light of these occurrences, this study will test whether the events of 2020 and 2022 have influenced the efficiency, in their weak form, of commodity markets, namely gold (XAU), silver (XAG), and platinum (XPT). The results suggest some persistence between the 2020 and 2022 events, but there is no evidence that investors can easily exploit this dependence, and these findings are crucial for investors trying to diversify their portfolios efficiently.

Because gold, silver, and platinum markets have become important components of both individual and institutional investment portfolios, this study contributes to the existing literature, particularly in the study of informational efficiency in precious metal markets. It is also important to understand the impact that the 2020 and 2022 events had on predictability in the spot prices of gold (XAU), silver (XAG), and platinum (XPT).

This study is organized as follows: part 1 is an introduction, and section 2 is a Literature Review of studies on predictability in commodities markets. Section 3 covers the data and methods. Section 4 contains the main results. Section 5 concludes.

2. LITERATURE REVIEW

Various scientific studies have examined the notion of asset return prediction through the examination of patterns that may impact commodity price information, namely precious metals. According to these studies, certain economic developments make the fast adjustment of asset values difficult, resulting in temporal gaps that investors might employ to take advantage of above-average returns without incurring additional risk (Dias & Santos, 2020; Dias et al., 2021; Vasco et al., 2021; Guedes et al., 2022).

In 2015, the authors Ntim et al. (2015) investigated the extent to which the predictability of gold spot prices can be explained by macroeconomic variable volatility in the spot prices of 28 global gold markets, with special attention on the random walk and martingale hypothesis, from January 1968 to August 2014. The authors show that gold markets in the UAE, Saudi Arabia, Indonesia, Egypt, Mexico, Nepal, Pakistan, Russia, and Vietnam are (un)efficient and persistent. For gold markets in Hong Kong, Japan, Switzerland, the United Kingdom, and the United States, the random walk and martingale hypothesis cannot be rejected, whereas the results for gold markets in Australia, Bahrain, Brazil, Canada, China, Germany, India, Malaysia, Singapore, South Africa, South Korea, Taiwan, Thailand, and Turkey are hybrid. Furthermore, Charles et al. (2015) highlight that the predictability of precious metals market returns has changed over time, i.e. the returns of gold and silver markets have been trending downwards, implying that the level of efficiency, in its weak form, of these markets has significantly improved.

Already in 2020, the authors Shahid et al. (2020) assessed whether the prices of NYSE commodities (gold, silver, and metal) fluctuate randomly. The authors show that commodities exhibit inefficient behavior throughout the sample period, demonstrating that past prices help predict future prices. Furthermore, investors can use time-varying information to reduce the risk of NYSE investment.

Pathak et al. (2020) investigated the predictability of gold, silver, platinum, and palladium spot prices and discovered that the degree of efficiency of metal prices fluctuates with time, with the silver market exhibiting the highest levels of efficiency. In addition, Shahid, Latif, et al. (2020) investigated the predictability of four commodities indexes, namely gold, metal, oil, and silver, in different crisis periods from 1963 to 2013. The authors show, using linear and non-linear testing, that commodities index returns were predictable (dependent) in certain crises but unpredictable in others.

In more recent studies, Okoroafor and Leirvik (2022) evaluated the efficiency of the spot crude oil (WTI) market to key events in worldwide financial and commodities markets, finding that the WTI market is persistent and (in)efficient during the financial crisis. In contrast, Kara et al. (2022) tested the efficient market hypothesis, i.e. the predictability of pricing patterns, for many non-renewable commodities, including gold, platinum, and silver, copper, zinc, aluminum, lead, tin, and nickel (1980-2019). Except for silver, the authors show that none of the prices can be described by the efficient market hypothesis, which states that prices follow stationary and predictable patterns related to global economic events. In addition, Mensi et al. (2022) investigated fractal behavior and long memory in major precious and industrial metals futures markets. The authors estimated the Hurst exponent and performed an asymmetric multifractal trend fluctuation analysis for this purpose (A-MF-DFA). According to the authors, gold has the least asymmetric multifractal behavior while silver has the most asymmetric multifractal magnitude. All metals markets exhibit negative persistence and positive anti-persistence. Precious metals were most inefficient in decline before and during the 2008 global financial crisis, the European sovereign debt crisis, and the oil crisis.

In summary, this paper aims to contribute to the provision of information to market agents trading the spot prices of gold (XAU), silver (XAG), and platinum (XPT), and to attempt to demonstrate whether the 2020 and 2022 events have caused predictability in the specific metal markets.

3. METHODOLOGY AND DATA

3.1. Data

The data analyzed are the spot prices of gold (XAU), silver (XAG), and platinum (XPT), from September 18th, 2017, to September 15th, 2022. To obtain more robust results, we divided the sample into two sub-periods: the first period is referred to as Calm is defined by an apparent calmness in the financial markets and comprises the period from 18 September 18th, 2017, to December 31st, 2019. The events of 2020 and 2022 characterize the second period, a highly complex period in international financial markets marked by events such as the pandemic outbreak caused by the appearance of coronavirus in the Chinese city of Wuhan in March 2020 and, later, the Russian invasion of Ukraine in the first quarter of 2022. The time scales are daily and were obtained from the Thomson Reuters Eikon database.

3.2. Methodology

In order to answer the research question, we will go through several steps. The first step is to evaluate the evolution of gold (XAU), silver (XAG), and platinum (Pt) (XPT). The sample will be characterized using descriptive statistics such as mean, standard deviation, asymmetry, and kurtosis, to validate whether we are dealing with normal distributions. To validate the results, we will estimate Jarque and Bera (1980). We will estimate the Dickey and Fuller (1981), Phillips and Perron (1988), Levin et al., (2002), and Im et al. (2003) tests to demonstrate that prices are stationary. The Clemente et al. (1998) test will be used to assess the most important breaks in the structure of spot prices of gold (XAU), silver (XAG), and platinum (XPT).

To answer the research question we will estimate Wright's (2000) model, through Wright (2000) Rankings and Signs Variance Ratios; to validate results we will apply Detrended Fluctuation Analysis (DFA) methodology. By assuming that the time series are non-stationary, this technique prevents false conclusions when the study focuses on the long-run relationships of the time series. Peng et al. (1994) created this methodology, which has its roots in the study of DNA behavior. This method was then used to investigate the behavior of financial series. DFA's interpretation is as follows: $0 < \alpha < 0{,}5$ anti persistent series; $\alpha = 0{,}5$ series features random walk: $0{,}5 < \alpha < 1$ persistent series.

4. RESULTS

Figure 1 shows the evolution of commodity markets, namely the spot prices of gold (XAU), silver (XAG) and platinum (XPT), in the period from September 18th, 2017, to December 31st, 2019, a period marked by relative stability in financial markets, as well as in the period from January 1st, 2020, to September 15th, 2022, a highly complex period in international financial markets marked by events such as the pandemic outbreak caused by the emergence of coronavirus in the Chinese city of Wuhan in March 2020 and later, in the first quarter of 2022, with the Russian invasion of Ukraine. Through graphical observation, it is noticeable that there are significant breaks in the structure of the time series, especially during the first and second quarters of 2020 and 2022. Authors Dias et al. (2022), and Zebende et al. (2022) support this evidence by highlighting large structural breaks in international capital markets.

Figures 2 and **3** show the evolution, in returns, of the financial markets under analysis and high dispersion around average (extreme volatility), and a certain synchronism in the movements of the time series can be observed. It's possible to confirm the existence of accentuated falls in structure in the markets under analysis, with special emphasis on the commodities markets, which were primarily felt in the last quarter of 2019 and first/second quarter of 2020, a period that was characterized as a bear market period due to a sharp drop in price indexes caused by the uncertainty triggered by the evolution of the global pandemic (Covid-19). In 2022, due to Russia's invasion of Ukraine, there are also structural breaks in the time series under study, however, they are less pronounced as compared to the influence of the Covid-19 pandemic.

Table 1 shows the main descriptive statistics of the returns of the time series, namely the spot prices of gold (XAU), silver (XAG), and platinum (XPT), for the two sub-periods under study, namely the Calm sub-period from September 18th, 2017, to December 31st, 2019, and the Stress sub-period from January 1st, 2020, to September 15th, 2022.

The values of average returns are shown in **Table 1**, which are consistent with classical financial theory dictates, that is, the longer the time interval, the average returns will tend toward zero. Overall, gold (XAU), had the highest average return in both subperiods under analysis, despite falling. It should also be highlighted that the commodities under research exhibited positive average returns during the calm subperiod; nevertheless, during the financial market Stress subperiod, not only did all of them become less profitable, but even platinum (XPT) showed a negative average return.

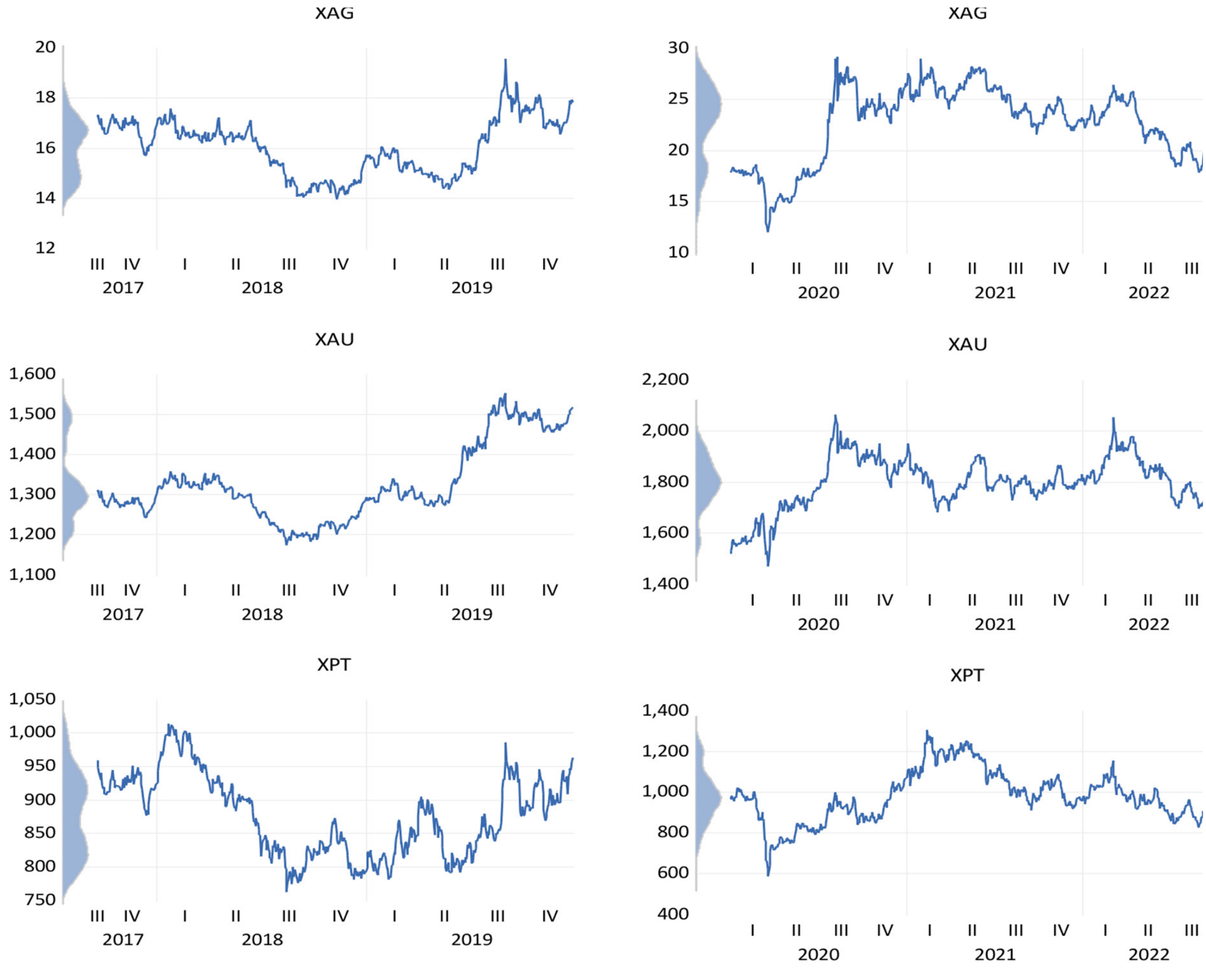

Figure 1. Evolution, in levels, of the commodity markets (XAG, XAU, XPT), for the period from September 18th, 2017, to September 15th, 2022

Source: Own elaboration

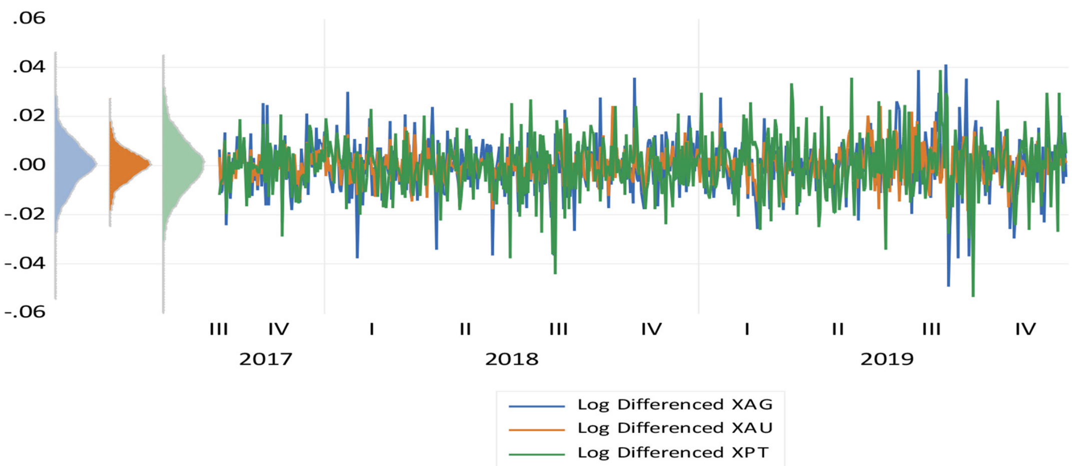

Figure 2. Evolution, in returns, of the commodity markets (XAG, XAU, XPT), in the period from September 18th, 2017, to December 31st, 2019

Source: Own elaboration

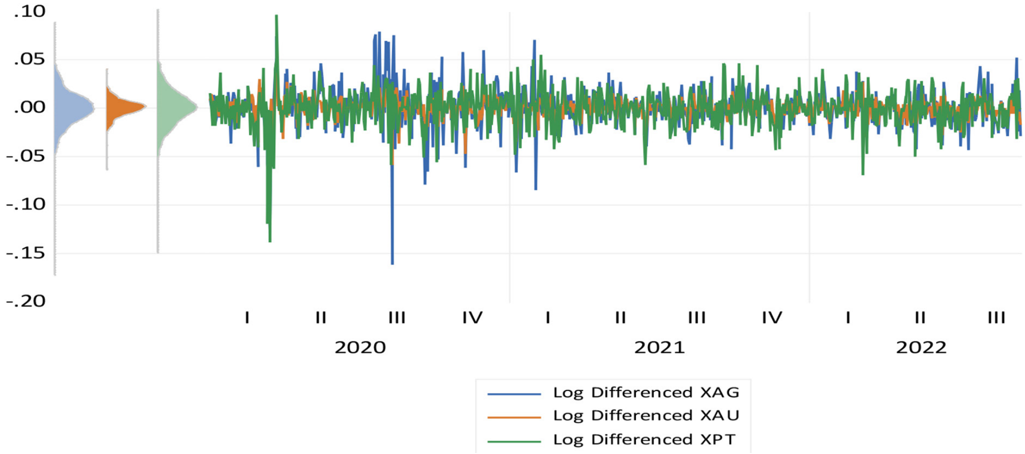

Figure 3. Evolution, in returns, of the commodity markets (XAG, XAU, XPT), in the period from January 1st, 2020, to September 15th, 2022

Source: Own elaboration

In terms of standard deviation, gold (XAU) is the riskiest asset in the calm subperiod. In comparison, all of the financial markets under consideration showed higher risk during the Stress subperiod. The results also show that the return series deviate from the normality hypothesis, which is validated by the Jarque and Bera (1980) test, as well as by analyzing the skewness and kurtosis coefficients, which are statistically different from those of a normal distribution, leading us to conclude that the return series analyzed are leptokurtic and asymmetric.

Table 1. Descriptive statistics, in returns, of the commodity markets (XAG, XAU, XPT) from September 18th, 2017, to September 15th, 2022

	Calm Period			Stress Period		
	18/09/2017 a 31/12/2019			01/01/2020 a 15/09/2022		
	XAG	XAU	XPT	XAG	XAU	XPT
Mean	5.97E-05	0.000252	5.26E-06	0.000100	0.000134	-8.66E-05
Median	0.000336	0.000270	0.000000	0.000536	0.001016	0.000649
Maximum	0.041407	0.024360	0.039076	0.079027	0.036340	0.097077
Minimum	-0.049225	-0.021652	-0.053648	-0.162015	-0.058927	-0.138772
Std.Dev.	0.010996	0.006550	0.011721	0.021290	0.009942	0.020139
Skewness	-0.244225	0.104835	-0.170491	-0.817372	-0.737945	-0.750538
Kurtosis	5.035149	4.047529	4.260143	11.07271	6.471347	8.376299
Jarque-Bera	108.2328	28.19906	42.10862	1998.483	419.1480	917.8575
Probability	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000
Sum	0.035392	0.149290	0.003122	0.070898	0.094422	-0.061224
SumSq.Dev.	0.071578	0.025401	0.081333	0.320018	0.069783	0.286347
Observations	593	593	593	707	707	707

Source: Own elaboration

When we are analyzing price indexes it is crucial to analyze the (non-)stationary nature of the time series. **Tables 2** and **3** analyze the stationary nature of the spot prices of gold (XAU), silver (XAG), and platinum (XPT), throughout the Calm and Stress subperiods, respectively.

The Levin et al. (2002) and Im et al. (2003) test postulate that the null hypothesis has unit roots, showing a probability lower than a significance level of 1%, in first differences, since it causes us to reject the null hypothesis.

Table 2. Stationarity tests of Dickey and Fuller (1981), Phillips and Perron (1988), Levin, Lin, and Chu (2002) and Im et al. (2003), applied to the commodity markets (XAU, XAG, XPT) under study over the period from September 18th, 2017, to December 31st, 2019

Method	Statistic	Prob.**	Crosssections	Obs.
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-56.9454	0.0000	3	1773
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-47.9240	0.0000	3	1773
ADF - Fisher Chi-square	505.978	0.0000	3	1773
PP - Fisher Chi-square	505.104	0.0000	3	1773

Note: ** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality

Source: Own elaboration

Table 3. Stationarity tests of Dickey and Fuller (1981), Phillips and Perron (1988), Levin, Lin, and Chu (2002) and Im et al. (2003), applied to the commodity markets (XAU, XAG, XPT), over the period from January 1st, 2020, to September 15th, 2022

Method	Statistic	Prob.**	Crosssections	Obs.
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-56.9413	0.0000	3	2118
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-48.1422	0.0000	3	2118
ADF - Fisher Chi-square	534.660	0.0000	3	2118
PP - Fisher Chi-square	534.821	0.0000	3	2118

Note: ** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality

Source: Own elaboration

In **Figure 4** it is possible to examine the most significant structure breaks, of the spot prices of gold (XAU), silver (XAG), and platinum (XPT), over the period from September 18th, 2017, to December 31st, 2019. The results of Clemente et al. (1998) test demonstrate that more significant breaks occur mostly when rumors of the advent of an infectious disease in the Chinese city of Wuhan, dubbed Covid-19, appear. Due to the evolution of the pandemic outbreak, there are also significant breaks in the time series structure in the early months of 2020. It should also be highlighted that platinum (XPT) moves more volatilely than gold (XAU) and silver (XAG).

Even though Russia's policy choice to conduct military operations on Ukrainian territory had a large-scale negative impact, commodity markets did not show sharp falls.

In **Tables 4** and **5** are presented the results of the non-parametric version of the Wright (2000) variance test for the two sub-periods under study, namely, the "Calm" period, which runs from September 18th, 2017 to December 31st, 2019, and the "Stress" period, which corresponds to the time lapse between January 1st, 2019, and September 15th, 2022, for the commodities of gold (XAU), silver (XAG), and platinum (XPT). This approach comprises the Rankings Variance Ratio and Signals tests, and the present statistics were calculated for lags from 2 to 16 days.

The results presented in **Table 4** show that during the Calm period, the random walk hypothesis is not rejected for all markets under analysis, which means, that during this period the changes in the price indexes XAG, XAU and XPT are i.i.d., so it is assumed that past price index movements or trends cannot be used to predict future price index movements.

During the Stress period, however, the random walk hypothesis is rejected for all commodity markets, including gold (XAU), silver (XAG), and platinum (XPT). During this period, we even find that the variance ratios are less than unity, which implies that the returns exhibit significant autocorrelation. These findings lead us to conclude that, regardless of the nature of the information, markets may overreact to it during the Stress period and end up correcting themselves in the following days. Zebende et al. (2022), Dias et al. (2022), and Guedes et al. (2022) validate these findings, revealing that the high prices sensitivity to new information during this period of high complexity in international financial markets is due to the climate of pessimism and uncertainty experienced by investors during the sample period, as a result of events such as the Covid-19 pandemic in 2020 and Russian invasion of Ukraine in 2022.

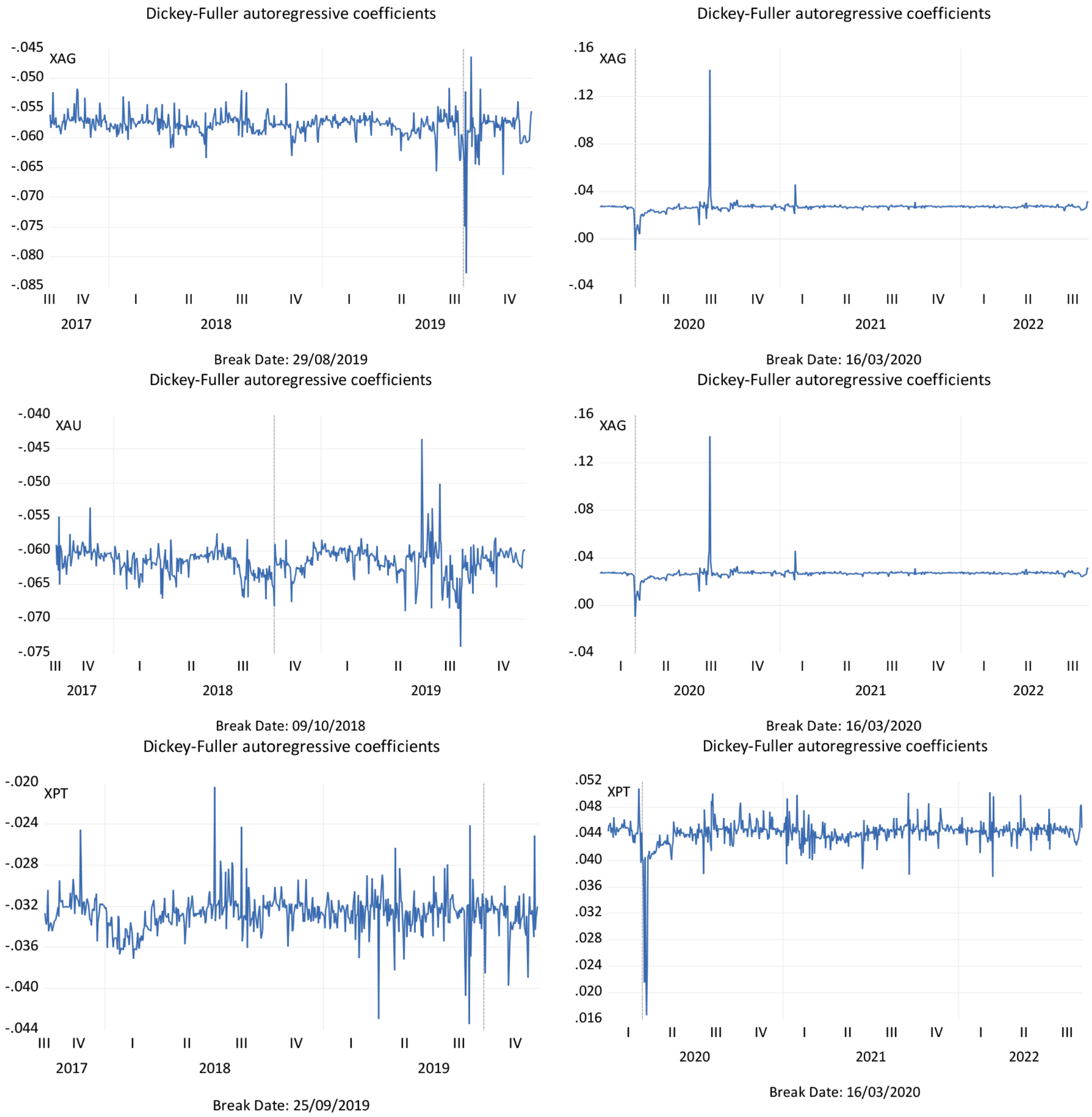

Figure 4. Evolution, in levels, of the commodity markets (XAG, XAU, XPT), for the period from 18 September 2017 to 15 September 2022

Source: Own elaboration

Table 4. Tests of Wright's (2000) Variance Ratios of Rankings and Signals, in returns, of commodity markets (XAG, XAU, XPT), over the period from September 18th, 2017, to December 31st, 2019

Null Hypothesis: XAG is a random walk				
Joint Tests		Value	df	Probability
Max |z| (at period 2)		2.131658	593	0.0890
Wald (Chi-Square)		16.09920	15	0.377
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.912463	0.041065	-2.131658	0.0360
3	0.870888	0.061216	-2.109108	0.0340
4	0.887535	0.076826	-1.463903	0.1410
5	0.875196	0.089969	-1.387182	0.1550
6	0.864278	0.101516	-1.336959	0.1760
7	0.867338	0.111925	-1.185278	0.2320
8	0.860704	0.121472	-1.146733	0.2460
9	0.846881	0.130339	-1.174770	0.2440
10	0.833241	0.138652	-1.202718	0.2350
11	0.814170	0.146501	-1.268458	0.2150
12	0.795844	0.153956	-1.326068	0.1950
13	0.778120	0.161070	-1.377536	0.1730
14	0.760766	0.167887	-1.424970	0.1590
15	0.752592	0.174439	-1.418303	0.1600
16	0.748872	0.180756	-1.389321	0.1650
Null Hypothesis: XAU is a random walk				
Joint Tests		Value	df	Probability
Max |z| (at period 13)		1.747963	593	0.2040
Wald (Chi-Square)		20.76580	15	0.1840
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.928226	0.041065	-1.747810	0.0790
3	0.896511	0.061216	-1.690551	0.0880
4	0.892039	0.076826	-1.405272	0.1620
5	0.870776	0.089969	-1.436313	0.1490
6	0.838329	0.101516	-1.592568	0.1070
7	0.823332	0.111925	-1.578453	0.1200
8	0.809609	0.121472	-1.567366	0.1240
9	0.794279	0.130339	-1.578350	0.1220
10	0.778460	0.138652	-1.597820	0.1150
11	0.754216	0.146501	-1.677693	0.0970
12	0.740452	0.153956	-1.685861	0.0970
13	0.718455	0.161070	-1.747963	0.0820
14	0.706922	0.167887	-1.745689	0.0810
15	0.709265	0.174439	-1.666683	0.0990
16	0.715834	0.180756	-1.572093	0.1300
Null Hypothesis: XPT is a random walk				
Joint Tests		Value	df	Probability
Max |z| (at period 16)		1.144655	593	0.5420
Wald (Chi-Square)		11.26668	15	0.7320
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.969029	0.041065	-0.754191	0.4550
3	0.956153	0.061216	-0.716268	0.4750
4	0.969207	0.076826	-0.400811	0.6810

5	0.957439	0.089969	-0.473063	0.6320
6	0.955149	0.101516	-0.441809	0.6500
7	0.942110	0.111925	-0.517228	0.6000
8	0.932909	0.121472	-0.552319	0.5910
9	0.908344	0.130339	-0.703208	0.4860
10	0.885651	0.138652	-0.824718	0.4200
11	0.859158	0.146501	-0.961370	0.3400
12	0.843360	0.153956	-1.017435	0.3000
13	0.830145	0.161070	-1.054539	0.2840
14	0.812988	0.167887	-1.113918	0.2620
15	0.801978	0.174439	-1.135192	0.2480
16	0.793096	0.180756	-1.144655	0.2410

Source: Own elaboration

Table 5. Tests of Wright's (2000) Variance Ratios of Rankings and Signals, in returns, of the commodity markets (XAG, XAU, XPT) over the period January 1st, 2020, to September 15th, 2022

Null Hypothesis: XAG is a random walk				
Joint Tests		Value	df	Probability
Max |z| (at period 2)		12.67728	706	0.0000
Wald (Chi-Square)		176.6346	15	0.0000
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.522884	0.037635	-12.67728	0.0000
3	0.373722	0.056104	-11.16287	0.0000
4	0.300005	0.070410	-9.941766	0.0000
5	0.250896	0.082455	-9.084983	0.0000
6	0.211422	0.093037	-8.475924	0.0000
7	0.183742	0.102577	-7.957514	0.0000
8	0.165742	0.111327	-7.493744	0.0000
9	0.139225	0.119454	-7.205923	0.0000
10	0.135944	0.127072	-6.799731	0.0000
11	0.129524	0.134266	-6.483229	0.0000
12	0.114931	0.141098	-6.272711	0.0000
13	0.109201	0.147619	-6.034465	0.0000
14	0.103157	0.153866	-5.828744	0.0000
15	0.101478	0.159871	-5.620300	0.0000
16	0.091801	0.165660	-5.482294	0.0000
Null Hypothesis: XAU is a random walk				
Joint Tests		Value	df	Probability
Max |z| (at period 2)		11.85102	706	0.0000
Wald (Chi-Square)		161.1216	15	0.0000
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.553981	0.037635	-11.85102	0.0000
3	0.358434	0.056104	-11.43536	0.0000
4	0.293553	0.070410	-10.03339	0.0000
5	0.252260	0.082455	-9.068433	0.0000
6	0.207382	0.093037	-8.519349	0.0000
7	0.188365	0.102577	-7.912437	0.0000
8	0.161292	0.111327	-7.533715	0.0000
9	0.142062	0.119454	-7.182167	0.0000
10	0.142438	0.127072	-6.748630	0.0000
11	0.129794	0.134266	-6.481221	0.0000

12	0.120490	0.141098	-6.233316	0.0000
13	0.113554	0.147619	-6.004977	0.0000
14	0.109981	0.153866	-5.784391	0.0000
15	0.107495	0.159871	-5.582663	0.0000
16	0.101736	0.165660	-5.422325	0.0000
Null Hypothesis: XPT is a random walk				
Joint Tests		Value	df	Probability
Max |z| (at period 2)		12.79182	706	0.0000
Wald (Chi-Square)		175.2677	15	0.0000
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.518574	0.037635	-12.79182	0.0000
3	0.376586	0.056104	-11.11182	0.0000
4	0.287103	0.070410	-10.12501	0.0000
5	0.236443	0.082455	-9.260258	0.0000
6	0.203024	0.093037	-8.566189	0.0000
7	0.183986	0.102577	-7.955130	0.0000
8	0.169627	0.111327	-7.458847	0.0000
9	0.142807	0.119454	-7.175936	0.0000
10	0.133193	0.127072	-6.821379	0.0000
11	0.133375	0.134266	-6.454552	0.0000
12	0.125228	0.141098	-6.199737	0.0000
13	0.116954	0.147619	-5.981943	0.0000
14	0.111292	0.153866	-5.775871	0.0000
15	0.109373	0.159871	-5.570916	0.0000
16	0.110238	0.165660	-5.371000	0.0000

Source: Own elaboration

The Detrended Fluctuation Analysis (DFS) approach was used to test the weak efficient market hypothesis in commodity markets, namely the spot prices of gold (XAU), silver (XAG), and platinum (XPT) from September 18th, 2017, to September 15th, 2022. To study two sub-periods, one marked by relative stability in international financial markets and another marked by high complexity in markets resulting from events such as the Covid-19 outbreak and the Russian invasion of Ukraine, the period under study was divided into two parts: a “Calm” period that runs from September 18th, 2017, to December 31st, 2019, and a “Stress” period that runs from January 1st, 2020, to September 15th, 2022.

Using the DFA technique the α parameter was calculated for each time series. The parameter α represents the correlation properties of time series, and means that if α = 0.5, there are no long-range correlations present in the series, remaining in an equilibrium situation. In turn, if the parameter remains between 0.5 and 1, the series is persistent, and the process is considered to be long-term dependent with positive correlations at all lags. These markets are associated with higher risk and (positive) persistence, allowing for abnormal profits through arbitrage and providing evidence against the efficient market hypothesis. If the series has an α parameter between 0 and 0.5, the series is antipersistent, and the process is considered to be long-run dependent with negative correlations at all lags, which is related to markets that exhibit rapid mean-reversion.

Analyzing **Table 6**, we can see a significant increase in the exponents for XAG (0.48 to 0.54) and for XPT (0.50 to 0.52). During the Calm period, the commodity XAG presented an anti-persistent long memory (α < 0.5), turning to a persistent movement during the crisis (α > 0.5).

Platinum (XPT), on the other hand, was in a situation of equilibrium during the period of so-called tranquility in international financial markets, before transitioning to a persistent state with the sequence of events beginning in 2020 ($\alpha > 0.5$). In turn, the commodity XAU experienced a decrease in the value of its exponent but remained antipersistent ($\alpha < 0.5$).

These findings show that prices do not fully reflect available information and that price changes are not i.i.d. In this view, this research has implications for investors since some returns in the markets under investigation may be predicted, offering the potential for arbitrage and abnormal profits, which implies gaining returns above the market average without incurring additional risk. These findings are consistent with those given by Dias et al. (2022), Zebende et al., (2022), and Guedes et al. (2022), all of which highlight the presence of long memories in periods of stress in international financial markets.

Table 6. Results of the DFA exponent, in returns, of the commodity markets (XAG, XAU, XPT), over the period from September 18th, 2017, to September 15th, 2022

Market	DFA (Calm)	DFA (Stress)
XAG	0.48 ≅ 0.0130	0.54 ≅ 0.0114***
XAU	0.48 ≅ 0.0245	0.46 ≅ 0.0068***
XPT	0.50 ≅ 0.0054	0.52 ≅ 0.0119***

Note: ***. **. *. represent significance at 1%. 5% and 10%. respectively.

Source: Own elaboration.

5. CONCLUSION

This article aimed to understand if the global pandemic of 2020 and the Russian invasion in 2022 caused predictability in the spot price formation of gold (XAU), silver (XAG), and platinum (XPT), in the period from September 18th, 2017, to September 15th, 2022. To answer the research question, we performed the Rankings and Signals test which allows evidencing, that in the Calm period, the random walk hypothesis is not rejected in the gold, silver, and platinum markets, meaning that spot prices are independent and identically distributed (i.i.d.), so it is assumed that their movements follow a random behavior. On the contrary, the random walk hypothesis is rejected in all commodity markets throughout the Stress period, with variance ratios below unity, meaning that returns exhibit significant autocorrelation. To validate, the results of the Detrended Fluctuation Analysis (DFA) exponent demonstrate that during the Calm period, silver (XAG) exhibited an antipersistent short memory ($\alpha < 0.5$), shifting during the crisis to a persistent movement ($\alpha > 0.5$). Platinum (XPT) was in a situation of equilibrium during the calm period in international financial markets, becoming persistent with the sequence of events beginning in 2020 ($\alpha > 0.5$). In turn, gold (XAU) decreased its antipersistence ($\alpha < 0.5$) through stress in international markets.

In conclusion, the authors provide significant evidence for regulators, supervisors, investors, and hedge managers who wish to invest in these markets by building strategies and diversifying their portfolios based on different frequencies. These results have significant implications for the role of gold, silver and platinum as investment assets.

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