

Araştırma Makalesi/Research Article

INVESTIGATION OF RATIONAL BUBBLES AND VOLATILITY SPILLOVERS IN COMMODITY MARKETS: EVIDENCES FROM PRECIOUS METALS

*EMTİA PİYASALARINDA RASYONEL BALONLAR VE VOLATİLİTE YAYILIMLARININ ARAŞTIRILMASI:
DEĞERLİ METALLERDEN KANITLAR*

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Abstract

Price bubbles which can be expressed as the deviation of the price of an asset from its fundamental value, have significant impacts on markets. The effects of the financial crisis that started with the burst of the housing bubbles in the USA in 2008 have spread all over the world and turned into a global crisis. In this study, the price bubbles of gold, silver, platinum and palladium in the commodity markets for the period between 01.01.2010-19.02.2019 were investigated. RtADF, SADF and GSADF methods were used to determine the formation and burst periods of price bubbles. As a result of the analysis, price bubbles were found in gold, silver and platinum, whereas no bubbles were found in palladium prices. Due to the close formation dates of these bubbles, whether there was any return or volatility spillover between gold, silver and platinum markets was investigated with VAR-EGARCH method. As a result of the study, it was found that there was a multiple spillover between the gold, silver and platinum returns. Thus, it was concluded that the price bubbles formed in precious metals triggered each other. Findings regarding the presence of price bubbles in the precious metal markets are crucial for traders in terms of trading timing. However, the findings related to the volatility spillover among precious metals are also important in terms of considering the effect of this spillover for the investors who provide hedging by precious metals.


Keywords: Rational Price Bubbles, Precious Metals, Commodity Markets, Volatility Spillover.


Öz

Bir varlığın fiyatının, varlığın temel değerinden sapması olarak ifade edilebilen fiyat balonları, piyasalar üzerinde önemli etkilere sahiptir. ABD’de 2008 yılında konut fiyat balonunun patlamasıyla başlayan finansal krizin etkileri tüm dünyaya yayılarak küresel krize dönüşmüştür. Bu çalışmada emtia piyasalarında yer alan değerli metallere altın, gümüş, platin ve paladyum fiyatlarında 01.01.2010-19.02.2019 dönemi için fiyat balonlarının varlığı araştırılmıştır. Araştırmada fiyat balonlarının oluşum ve patlama dönemlerini ortaya koyabilen RtADF, SADF ve GSADF yöntemleri kullanılmıştır. Analizler sonucunda altın, gümüş ve platin fiyatlarında balona rastlanırken, paladyum fiyatında herhangi bir balonun varlığına dair kanıt bulunamamıştır. Söz konusu balonların birbirine yakın tarihlerde meydana gelmesi nedeniyle de ayrıca altın, gümüş ve platin piyasaları arasında getiri ve volatilité yayılımının bulunup bulunmadığı VAR-EGARCH yöntemi ile araştırılmıştır. Araştırma sonucunda da altın, gümüş ve platin getirileri arasında çoklu bir yayılım olduğu tespit edilmiş, böylece kıymetli madenlerde oluşan fiyat balonlarının birbirini tetiklediği sonucuna ulaşılmıştır. Kıymetli metal piyasalarında fiyat balonlarının varlığı ile ilgili elde edilen bulgular, bu piyasadaki yatırımcılar için işlem zamanlaması açısından önemlidir. Diğer taraftan kıymetli metaller arasındaki volatilité yayılımı ile ilgili bulgular da kıymetli metallere finansal korunma sağlayan yatırımcıların kıymetli metaller arasındaki çok yayılımlarını dikkate alması açısından önemlidir.

Anahtar Kelimeler: Rasyonel Fiyat Balonları, Değerli Metaller, Emtia Piyasaları, Volatilité Yayılımı.

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GENİŞLETİLMİŞ ÖZET

Çalışmanın amacı, emtia piyasalarından değerli metaller sınıfına dahil olan emtia (altın, gümüş, platin ve paladyum) fiyatlarının oluşumunda piyasa temelinden uzaklaşıp uzaklaşmadığının, diğer bir ifadeyle fiyat balonlarının araştırılmasıdır. Söz konusu metallerden altın ve gümüş dışındaki emtialarla ilgili fiyat balonu çalışmasına bugüne kadar hiç rastlanmamıştır. Bu durum çalışmayı özgün kılmaktadır. Çalışmanın ikincil amacı ise, değerli metaller piyasalarının herhangi birinde oluşan getiri ve volatilitenin diğer değerli metaller piyasalarına da yayılıp yayılmadığının belirlenmesidir.

Çalışmada fiyat balonunun varlığını tespit etmek için altın, gümüş, platin ve paladyum fiyatlarında 01.01.2010-19.02.2019 dönemine ait günlük frekanslı veriler dikkate alınmıştır. Son yıllarda geliştirilen RtADF, SADF ve GSADF yöntemleri uygulanmıştır. Bu yöntemler, fiyat balonunun oluşum ve sona erme dönemlerini ortaya koyabilmesi açısından önem arz etmektedir. Çalışmada ayrıca değerli metaller piyasalarındaki getiri ve volatilitenin yayılımının tespiti için VAR-EGARCH yöntemi uygulanmıştır.

Analizler sonucunda altın, gümüş ve platin fiyatlarında balona rastlanırken, paladyum fiyatında herhangi bir balonun varlığına dair kanıt bulunamamıştır. Diğer bir ifadeyle paladyum fiyatları esas olarak piyasa temellerinden kaynaklanmaktadır. Çalışmada ayrıca altın, gümüş ve platin fiyatlarında oluşan balonların birbirine yakın tarihlerde meydana gelmesi nedeniyle söz konusu piyasalar arasında getiri ve volatilitenin yayılımı olabileceği sorusunu akla getirmektedir. Bu nedenle söz konusu finansal varlıklar arasında getiri ve volatilitenin yayılımlarının olup olmadığı Koutmos (1996) tarafından geliştirilen VAR-EGARCH modeli yardımıyla ayrıca incelenmiştir. Araştırma sonucunda altın, gümüş ve platin getirileri arasında çoklu bir yayılım olduğu tespit edilmiş, böylece kıymetli madenlerde oluşan fiyat balonlarının birbirini tetiklediği sonucuna ulaşılmıştır.

INTRODUCTION

The commodity market is an important market, consisting of assets used or consumed in daily life, but also subject to large investments and speculative transactions. Commodity markets have received billions of dollars of investment from institutional investors since the beginning of this century and therefore commodities constitute a significant part of many investors' portfolios. As a result, it is stated by many people that there is a structural change in commodity markets, which is called as financialization of commodities (Baur and Glover, 2012: 5).

The global financial turmoil in 2008-2009 in the United States and its impact on economies, has led to increased interest in financial bubbles (Phillips and Yu, 2011: 456). The concept of the bubble mentioned here is simply defined as "a deviation of the market price from the asset's fundamental value" (Scherbina, 2013: 3). The speculative bubbles in the stock exchanges mean the systematic deviation of an asset from its fundamental value (Homm and Breitung, 2012: 200). If the fundamental factors in the price of an asset do not justify such a price, then the existence of the bubbles in the price can be mentioned (Su et al., 2017a: 2). In many editions, the term financial bubble refers to a situation in which the price of a financial asset increases rapidly and this increase occurs in a speculative manner, unlike the value that is considered to be the real value of the asset (Phillips and Yu, 2011: 459-460).

Asset bubbles can be divided into two as rational and irrational bubbles. A rational bubble is the price that investors are willing to pay more than the value determined according the discounted dividend flow with the expectation that they may be sold at a price over the current dividend value in the future and their high price will be an equilibrium price (Gurkaynak, 2008: 166). According to this definition, a rational bubble is the price at which an asset can be sold to someone else profitably, although it is known that the price of an asset is higher than the market price. The concept of rational bubble was first developed by Blanchard and Watson (1982) (Chancellor, 2010: 119). The irrational bubble in asset prices is the price that occurs when investors believe that the market is over-valued, but does not focus on the difference between investor actions and beliefs (Lucey and O'Connor, 2013: 56).

In the past centuries, world history has witnessed important bubbles, each of which may be the subject of research. The most well-known of these are: Dutch tulip mania of 1634, France Mississippi bubble of 1717, South Sea bubble of England in 1720, South American mining bubble of 1822-1825, the Railway Mania of UK in 1845, real estate and stock bubble before Great Depression in the US in 1929, the Japanese asset price bubble in the 1980s and Kuwait Souq Al-Manakh bubble in the early 1980s (Chancellor, 2010).

Despite the ease of accessing and analyzing information with the developing technology, important crises have been experienced in the near future due to such important bubble formation and the burst of bubbles. The dot.com bubble, which resulted in the collapse of the prices of technology companies in the US in 2000, the housing price bubble, and the oil price bubbles in the US in 2008 are the price bubbles that have a significant impact on the markets. For example, in the oil price bubble event, crude oil prices increased explosively from \$100 in January 2008 to \$147 by July 2008 and then dropped to \$30 at the end of 2008. Thus, the bubble in crude oil prices burst in August 2008 (Tokic, 2010: 6009-6012). In addition to the economic factors such as supply and demand, speculative activities such as commodity futures contracts are also effective in the price formation related to oil (Su et al., 2017a: 1).

Gold one of the most important commodities in commodity markets and covered in this study, is also an asset that has been widely bought by the major central banks, and thus its price has been continuously increasing (Lucey and O'Connor, 2013: 53). However, gold is seen as a globally accepted currency that does not lose its purchasing power and a commodity the weight of which in the portfolio is significantly increased by financial market participants during periods of financial difficulties (Bialkowski et al., 2011: 12). Since the gold stock, which is equal to approximately 50 times the annual average production, is much larger than the annual gold production in general, there is no significant change in the supply of gold, and the production of gold is not affected by the seasonality. Gold is traded around the world for 24 hours, helping to ensure that any deviation from the fundamental value of the gold price can be processed quickly. Given these characteristics, the gold market should give little opportunity for speculative bubbles (Bertus and Stanhouse,

2001: 80-81). Blanchard and Watson (1982) contradicts the idea and claims that bubbles are more probable in the markets where the fundamental elements such as the gold market are difficult to evaluate, whereas in markets which have a clearly defined basis such as blue chip stocks or perpetuities, the formation of bubbles is less likely (Blanchard and Watson, 1982: 8-9).

The burst of price bubbles has had important results such as insecurity in the markets, disappointment, illness, and death due to suicide (Chancellor, 2010: 112). It is critical to locate asset price bubbles so that appropriate policies can be implemented to reduce disastrous consequences when bubbles burst (Su et al., 2017a: 2). The identification of price bubbles may be the starting point for the prevention of the downward price risks of the parties. Thus, buyers will be able to avoid buying assets while there is a bubble period in the market while sellers will have the opportunity to sell their assets before the prices fall significantly (Pan, 2018: 110). In addition, considering the dates of the formation of the price bubbles, the reasons and/or results may be investigated and measures may be taken to prevent the formation of bubbles. Blanchard and Watson (1982) also stated that a bubble for the price of any asset may affect the prices of other assets.

The primary objective of this study is to investigate whether the price of commodities in the class of precious metals (gold, silver, platinum and palladium) is deviated from the market fundamental, that is, price bubbles. To date, no studies regarding price bubbles in the class of precious metals in commodities other than gold and silver have been found. This makes the study unique. The secondary aim of the study is to determine whether the return and volatility in any of the precious metals markets are spread to other precious metals markets. In the study, RtADF, SADF and GSADF methods developed in recent years will be applied to determine the presence of price bubbles. These methods are important in terms of revealing the formation and end periods of the price bubbles. As a result of the price bubble analysis, it was seen that bubble formations occurred at close dates, which raises the question of whether there is volatility spillover between the precious metals. So, VAR-EGARCH method will be applied to determine the return and volatility spillover in the precious metals markets in this study. In this study, it can be said that this study is quite comprehensive due to the investigation of volatility spillover along with price bubbles, the use of multiple methods in the research of those bubbles, and the large number of variables and observations. Thus, the results of the study will be able to contribute significantly to the literature as well as to the market participants.

After the explanations mentioned in the introduction part of the study, the studies in the literature related to the topic will be included in the first section. In the second section, the method of the study will be covered. In the third section, the data used in the study and the descriptive statistics of the data will be explained. In the fourth chapter, the empirical findings will be given. Finally, the results of the study will be presented.

1. LITERATURE REVIEW

Many studies on price bubbles which have significant impacts on financial markets, have been carried out in recent years. The studies have been generally focused on four topics as studies on stock markets (Diba and Grossman, 1988; Phillips et al., 2011; Phillips et al., 2013; Harvey et al., 2015; Phillips et al., 2015; Caspi and Graham, 2018) studies on real estate markets (Hessel and Peeters, 2011; Phillips and Yu, 2011; Scherbina, 2013; Zeren and Erguzel, 2015; Abildgren et al., 2018) studies on the commodity markets that will be explained in detail below and other financial assets (Korkmaz et al., 2016; Ceylan et al., 2018; Zeren and Esen, 2018). The studies of Flood and Garber (1980) and Blanchard and Watson (1982) are among the pioneering studies on financial bubbles. Flood and Garber (1980) analyzed the existence of the bubble in the money supply and inflation data during the German hyperinflation period. The results support the hypothesis that no price level bubbles were present in the money supply and inflation data during the German hyperinflation period. In another pioneering study, Blanchard and Watson (1982) investigated the presence of price bubbles in the gold market with weekly data for the period January 1975-June 1981. According to the results of the run test conducted in the study, there were no bubbles in the gold prices.

The studies on bubbles in the commodity markets have focused particularly on the oil, which is in the energy products class. Lammerding et al. (2013) investigated the presence of speculative bubbles in the heavily financialized oil market due to the repeated sudden increases and collapses in prices. The results of study using the conformity return approach in theoretical modeling to converge to the fundamental value of the oil price, there is strong evidence for the existence of speculative bubbles on the petroleum price dynamics in recent years. As seen, the intense financialization in the oil market may contribute the idea that prices in this market may include speculative bubbles.

Balcilar et al. (2014) have aimed to determine the bubbles and collapses in oil prices since 1986. As a result of the study, they found four different permanent bubbles and the collapse periods in crude oil prices, two of them before 2000, two after 2000. However, the authors stated that they believed that these bubbles were not due to speculative actions but rather to non-oil economic or political events. They also stated that more research is needed to better understand the role of futures markets in the formation of oil prices.

Zhang and Yao (2016) investigated the existence and dates of dynamic bubbles in oil prices with the help of the log-periodic power law (LPPL) model and state-space model. According to the results of the study, oil price bubbles were found only in November 2001-July 2008 period. Moreover, it is concluded that crude oil and diesel prices were mostly driven by bubbles but that the price of gasoline was mainly market-based.

Su et al. (2017a) investigated the presence of multiple bubbles in crude oil prices. According to the empirical results of the study, in the 1986-2016 period, there were six price bubbles deviating from the fundamental value calculated on the basis of the market basis in the price of oil, and the date of formation of the bubbles (1990, 2005, 2006, 2008 and 2015) corresponded to certain events in the policy and financial markets.

Another market that comes to the fore in the studies on commodity markets is the gold market. Bertus and Stanhous (2001) conducted dynamic factor analysis to investigate the presence of price bubbles in the gold futures markets. According to the results obtained from the study and to the test statistics in traditional significance levels (5%), there was very little evidence of rational speculative bubbles in the gold futures markets, but there was a strong evidence of 10% significance. In addition, these bubble formations have been associated with historical events (silver crisis, bank fear, Black Monday, European economic crisis, Gulf war).

Bialkowski et al. (2011) investigated whether the fast-growing investment activities triggered a new asset price bubble, based on the gold price increase. Risk free interest rate and spot and futures prices of gold were used to determine the fundamental price of gold. According to Markov Switching ADF test results, speculative bubbles for the period of 1978-2010 were not detected in the gold price.

Baur and Glover (2012) investigated the presence of bubbles in the gold market for the period of January 1970-August 2012 with both daily and monthly frequency data. As a result of the study, similar findings were found in daily and monthly test results and bubble-like price characteristics were found in gold prices. It was also stated that the results of this estimation meant that the role of gold as a value storage and a safe haven was under threat.

Lucey and O'Connor (2013) investigated the financial leasing rates of gold as a measure of the fundamental value and investigated whether there were any rational speculative and periodically burst bubbles at the gold spot price. As a result of the study, there was some evidence that there were bubbles in the gold prices for the constant variance model.

Koy (2018) examined the existence of bubbles at some metal futures prices (copper, lead, nickel, zinc and aluminum) in the commodity market of India (MCX). According to SADF and GSADF test results, bubbles were found at the futures prices of copper, lead, nickel and zinc in India Commodity Derivatives Exchange (MCX), whereas no bubble was found in aluminum future prices.

Pan (2018) studied price bubbles in precious metals (spot gold, spot silver, gold futures and silver futures), also the relationship between bubbles and market sentiments (VIX). Inflation rate, 10 year US

government bond returns and US dollar index were included as control variables in the study. The results showed the existence of price bubbles in spot gold, spot silver, gold futures and silver futures markets.

In some studies in the literature, different class of commodity products are included together or separately. Pindyck (1993) examines the ability of the present value model to explain the pricing of storable goods (heating oil, copper, timber and gold). The reimbursement flow for commodities (return on conformity) is directly measured in terms of spot and futures prices, if futures markets are effective. According to the results of the study, it was seen that the prices of the three products (copper, timber and gold) included in the analysis deviated from the fundamental prices at least temporarily.

Gilbert (2010) investigated the possible price impact of speculative bubbles and index based investment activity on commodity futures prices between 2006 and 2008. In the study, the prices of crude oil, three non-ferrous metals (aluminum, copper and nickel) and three agricultural products (wheat, corn and soybean) were examined. As a result of this study, strong price bubbles were observed in copper and soybean market but weak price bubbles were determined in crude oil and nickel market. Price bubbles were not found in the aluminum, corn and wheat markets. Moreover, there was strong evidence that index-based investments contributed to the rise in oil and metal prices between 2006 and 2008, while weak evidence on grain prices was found.

After briefly referring to the dot.com bubble that took place in the 2000s, Tokic (2010) made theoretical explanations about the causes and consequences of the oil and housing price bubbles in 2008. As a result of the study, it was claimed that the 2008 oil price bubble was designed either directly or indirectly by the US central bank FED to protect against the deflation due to the collapse of the housing market and the resulting credit crisis.

Phillips and Yu (2011) provide an empirical study of price bubble characteristics in a number of key financial variables for a period of time including subprime crisis and global impacts. In this context, primarily the housing price index (S&P Case-Shiller Composite-10), crude oil and bond price (the spillover between Baa and Aaa) were included in the study. A second set of commodities, such as monthly heating fuel, coffee, cotton, cocoa, sugar and nutrient cattle prices, which were discounted by using the consumer price index, were also included in the study to check whether the empirical bubble properties in these series are valid for other products. As a result of the study, the housing bubble, which started in February 2002 and ended in December 2007; crude oil price bubble, which started in March 2008 and ended in July 2008; and bond price bubble, which started on 22 September 2008 and ended on 20 April 2009 were found. In addition, according to the results of the study using secondary data to test whether the bubble properties were valid for other products, a price bubble that started in March 2008 and ended in August 2008 was determined in heating fuel prices, which was similar to the crude oil prices. However, no bubble was found in coffee, cotton, sugar and nutrient cattle prices.

Homm and Breitung (2012) presented alternative tests for price bubbles. They also investigated more convenient estimators for the determination of the date of breakdown, i.e. the date when bubble formation began. Various stock indices (Nasdaq Composite, Nikkei225, S&P500, FTSE100, Hang Seng and Shanghai), various housing indices (USA, UK, Spain and Japan) and crude oil and gold price variables were used in the analyzes. According to the results of daily, weekly and monthly data on the commodity market, price bubbles were determined at 10% significance level in all data frequencies in gold prices, while no price bubble was detected in crude oil prices.

Su et al. (2017b) investigated whether or not multiple bubbles were present at the price of iron ore. According to the results of the study, they determined the existence of four bubbles in iron ore prices between January 1980 and December 2016. While the first three bubbles were explained by the extreme demand from China, limited supply, a high level of industrial density and an annual reference pricing mechanism, the last bubble was explained with the negative impact of the 2008 global financial crisis.

When the studies in the literature on the existence of bubbles in commodity markets are examined, it is noteworthy that gold and oil variables are generally used in the studies. Another point that is noteworthy is

the determination of the price bubble in the gold market, which is seen as a safe haven asset in financial markets.

There are also a significant number of studies on the volatility spillover in commodity markets, which constitute the other purpose of the study. Ewing and Malik (2013), Lau et al. (2017) studied volatility spillover between different commodity classes, including the precious metals.

Ewing and Malik (2013) examined the volatility of gold and oil futures, including structural breaks. As a result of the study, it was found that there was a significant volatility spillover between gold and oil returns.

Lau et al. (2017) investigated volatility spillover relationships between gold, silver, platinum palladium, oil and global capital ETFs. The results emphasized the role of gold ETFs as the most effective market and that gold is the main source of return spillover in white metal ETF markets. It was determined that the effect of gold on white precious metals was higher than oil or stocks.

Morales (2008), Sensoy (2013), Kirkulak and Lkhamazhapov (2017) investigated the volatility spillover of the commodities included in the precious metals. Morales (2008) investigated the nature of volatility spillover between precious metals returns. The results demonstrated evidence for two-way volatility spillover in almost all cases except gold. However, while gold has an effect on all markets, there is little evidence that other precious metals affect the gold market.

Sensoy (2013) investigated the volatility shifts and spillover of precious metals. As a result of the study, it was determined that gold had a volatility shift contagion effect on all precious metals, but other precious metals had no such effect on gold. Similarly, it was found that silver had a unidirectional volatility shift contagion effect on platinum and palladium, but platinum and palladium did not have a volatility shift contagion effect on other precious metals.

Kirkulak and Lkhamazhapov (2017) investigated the relationship between precious metals traded in Russia. The results showed that precious metals are highly related to each other.

When the literature on the volatility spillover among precious metals is evaluated in general, it can be said that gold has an effect on all precious metals.

2. METHOD

This section first describes the methods of RtADF, SADF and GSADF for the investigation of price bubbles in commodities that belong to the precious metals class. Then, VAR-EGARCH method will be used to determine return and volatility spillover in precious metals markets.

2.1. RtADF, SADF and GSADF Methods

Philips et al. (2011) and Phillips et al. (2013) proposed new recursive regression methods to analyze financial bubbles in asset prices. Unit root tests developed by Philips et al. (2011) and Phillips et al. (2013) are based on the recursive and rolling ADF test, which enables the identification and stigmatization of bubble formation in the data. Such tests measure that there is a unit root in the null hypothesis. In the alternative hypothesis of the test, it is emphasized that the series exhibits a slightly explosive process. These tests are based on the right tail variations of the ADF unit root test (Caspi, 2016).

The right-tail unit root test developed by Phillips et al. (2011) addresses the shortcomings of previous unit root tests. With the developed SADF unit root test, a recursive procedure is presented to test the explosive behaviors of financial assets, the origin of the economic exhaustion of the asset in question, the determination of the point of collapse and the establishment of confidence intervals for explosive growth rates in financial assets (Phillips et al., 2011).

Phillips et al. (2013) assumes an asymptotically negligible shift with a random walk process as in Equation 1 below.

$$y_t = dT^{-\eta} + \theta y_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim (\text{IID}) N(0, \sigma^2), \quad \theta = 1 \quad (1)$$

In Equation 1, the term "d" is the term constant; " η ", T is the coefficient that controls the slip size in the sample size; " y_{t-1} " means a delayed value of the respective asset series; " ε_t " represents the error term with constant variance that has mean 0.

The SADF test proposed by and Phillips et al. (2011) is based on recursive regression analysis. A fixed startup window and the ADF statistics in an expanding window are calculated for the data set (Caspi, 2016). When financial bubble formation involves multiple bursts and crashes in the financial time series, the SADF test may be inadequate in detecting these occurrences, thus failing to detect possible rational bubble formation. This weakness of SADF method has been tried to be eliminated by generalized sup ADF (GSADF) method in the presence of high frequency and multiple financial bubble doubts (Phillips et al., 2013: 4).

As suggested in the SADF test, instead of fixing the starting point of recursion on the first observation, the GSADF test extends the scope of the sample by changing both the starting point and the end point of recursion in a feasible flexible window range. The GSADF test developed by Phillips et al. (2013) performs better than the SADF test to detect financial bubble behaviors when a large number of events occur in the data, because financial bubble formations cover more sub-samples for the investigated series and have more window flexibility (Phillips et al., 2013). The GSADF test has the flexibility to detect multiple bubbles as compared to other right tail tests because it replaces the fixed window width with the varying start-up period by using the simulation technique (Ceylan et al., 2018: 268). The following GSADF test statistic is obtained by expanding the repeated right-tailed ADF test with varying sub-sample start and end points (Ceylan et al., 2018: 267).

$$\text{GSADF}(r_0) = \sup_{r_2 \in [0, r_2, r_0]}^{r_2 \in [r_0, 1]} \{ \text{ADF}_{r_1, r_2} \} \quad (2)$$

The GSADF test statistics calculated with the help of Equation 2 above are compared with the critical values calculated as a result of Monte Carlo simulations. If the GSADF test statistics are greater than the critical values, the null hypothesis claiming the absence of financial bubbles is rejected.

2.2. VAR-EGARCH Method

The fat-tailed characteristics of the financial time series cause the error term obtained from the established models not to have a homoscedastic. For this reason, the ARCH model was developed by Engle (1982) for financial time series with heteroscedasticity. Afterwards, GARCH model was developed by Bollerslev (1986) to eliminate the shortcomings of the ARCH model and to consider the lagged values of conditional variance from volatility modeling.

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^p \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^q \beta_j \sigma_{t-j}^2 \quad (3)$$

In the GARCH (p, q) model, both the squares of the delayed values of the error terms used in the ARCH model (ε_{t-i}^2) and the delayed values of the conditional variance terms (σ_{t-j}^2) are included (Bollerslev, 1986: 308). In both ARCH and GARCH models, the effect of information shocks on the market is considered symmetrically. For this reason, Nelson (1991) developed the EGARCH model, which also considers the effect of asymmetry on information shocks reaching the market. In the EGARCH model, the magnitudes and signs of the delayed values of the errors are considered in the conditional variance equation.

$$\ln \sigma_t^2 = \alpha_0 + \sum_{j=1}^p \beta_j \ln(\sigma_{t-j}^2) + \sum_{i=1}^q \alpha_i \frac{|\varepsilon_{t-i}|}{\sqrt{\sigma_{t-i}^2}} + \sum_{i=1}^q \gamma_i \frac{\varepsilon_{t-i}}{\sqrt{\sigma_{t-i}^2}} \quad (4)$$

Where σ_t^2 , is known as the conditional variance. The α_i parameter represents a magnitude effect or the symmetric effect of the model, β measures the persistence in conditional volatility irrespective of anything happening in the market. The γ_i parameter measures the asymmetry or the leverage effect, the

parameter of importance so that the EGARCH model allows for testing of asymmetries. When $\gamma < 0$, then bad news generate more volatility than good news.

Koutmos and Booth (1995) developed the VAR-EGARCH model which considers volatility and return by using the VAR model which was developed by Sims (1980) as a system of simultaneous equations and used to detect the short-term interaction, and by using the EGARCH model developed by Nelson (1991).

In Equation 5, which represents the mean equation of VAR-EGARCH model developed by Koutmos (1996), it is tried to determine the short-term interaction between the lagged returns of each precious metal and the lagged returns of other precious metals. The coefficient $\beta_{i,j}$ for $i \neq j$ reveals lead/lag relationships between markets. Equation 6, which represents the variance equation of the model, determines the volatility of information shocks of the precious metal markets in other markets. For $i \neq j$, $\alpha_{i,j}$ gives information about volatile spillover among markets. The coefficient γ_i represents volatility persistence. δ_j in Equation 7 represents the effect of asymmetry (Koutmos, 1996: 977, 978).

$$r_{it} = \beta_{i,0} + \sum_{j=1}^N \beta_{i,j} r_{j,t-1} + \varepsilon_{i,t} \quad (5)$$

$$\sigma_{i,t}^2 = \exp\{\alpha_{i,0} + \sum_{j=1}^N \alpha_{i,j} f_j(z_{j,t-1}) + \gamma_i \ln(\sigma_{i,t-1}^2)\} \quad (6)$$

$$f_j(z_{j,t-1}) = (|z_{j,t-1}| - E|z_{j,t-1}|) + \delta_j z_{j,t-1} \quad i, j = 1, 2, 3 \dots N, \quad i \neq j \quad (7)$$

3. DATA AND DESCRIPTIVE STATISTICS

Of the precious metals used in the study, the data regarding gold and silver were daily frequency data covering 01.01.2010-08.02.2019 and platinum and palladium data were between 01.01.2010-19.02.2019. The data regarding the US dollar was obtained from Bloomberg data terminal. The analysis was performed with the help of WinRATS and EViews10 econometric package programs. $\ln(p_t/p_{t-1})$ logarithmic return was used to measure return and volatility. The graphs of the precious metal return series within the scope of the study are shown below.

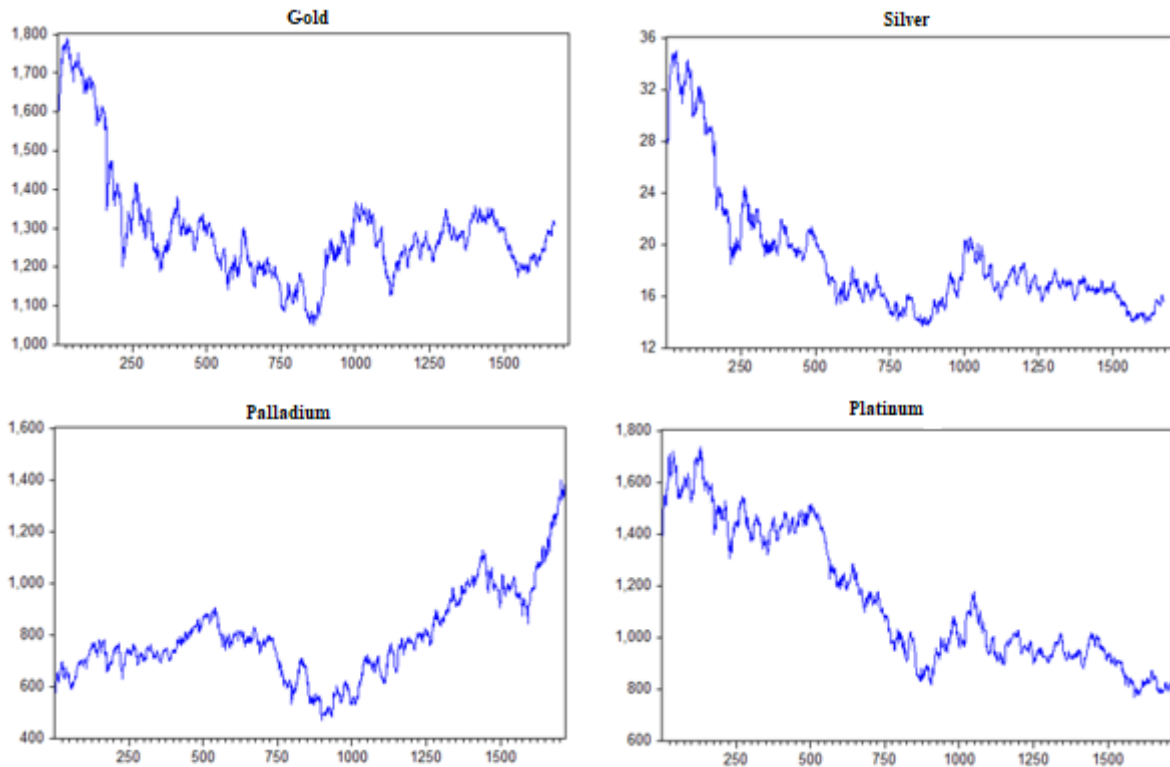


Figure 1. Time Charts of Precious Metals

When the time charts of precious metals are examined, it is seen that the sudden price movements in gold and silver prices are higher than palladium and platinum. It should be investigated with right tail unit root tests whether sudden price movements are rational price bubbles. Before starting the analysis, descriptive statistics of precious metals included in the study are given in Table 1 below.

Table 1. Descriptive Statistics of Precious Metals

	Gold	Silver	Palladium	Platinum
Mean	1.293,966	18,84105	790,3805	1.144,792
Maximum	1.790,950	35,01000	1.403,350	1.736,090
Minimum	1.051,110	13,68000	471,5000	769,1200
Std. Dev.	145,7838	4,733692	168,6758	263,0579
Skewness	1,666172	1,837484	0,907701	0,501429
Kurtosis	5,751544	5,781486	4,051779	1,834225
Jarque-Bera	1.301,061	1.479,863	315,2876	169,3756
Numbers of Observation	1672	1672	1719	1719

When the descriptive statistics of the daily precious metal prices included in the analysis are analyzed, it is seen that the standard deviation values of silver are the lowest in the other three precious metals. The standard deviation difference between silver and other metals is also quite high. In addition, it is seen that all precious metal price series are skewed to the right compared to normal distribution and that the value of the precious metals other than platinum is greater than 3 with respect to normal distribution. The density functions of the series also visually prove that they are skewed to the right according to the normal distribution. Figure 2 below shows density charts for commodity metal prices.

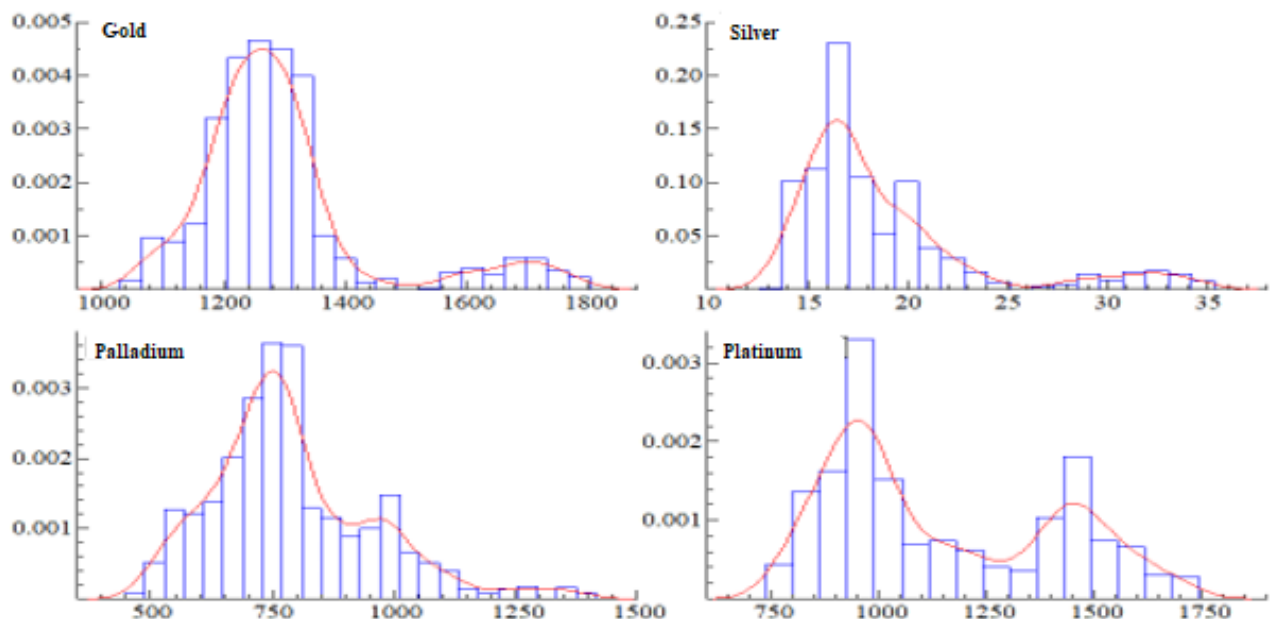


Figure 2. Density Charts of Metals Prices

4. EMPIRICAL FINDINGS

In this part of the study, the price bubbles in the commodities belonging to the precious metals class are investigated and then the volatility spillover analysis among the related variables is given. To determine the price bubbles in precious metals, Table 2 below shows the RtADF, SADF and GSADF test results for precious metals.

Table 2. RtADF, SADF and GSADF Test Results for Precious Metals

	Window Size	Test Statistics	Monte Carlo Based Critical Values		
			%99	%95	%90
RtADF_{Gold}	20	4.061799***	0.754335	0.018360	-0.359842
SADF_{Gold}	20	1.919425**	2.489408	1.767246	1.507426
GSADF_{Gold}	20	4.499835***	3.829156	3.106085	2.928100
RtADF_{Silver}	20	2.256547	0.754335	0.018360	-0.359842
SADF_{Silver}	20	0.873221	2.489408	1.767246	1.507426
GSADF_{Silver}	20	3.073680*	3.829156	3.106085	2.928100
RtADF_{Palladium}	20	1.431087	0.754335	0.018014	-0.363603
SADF_{Palladium}	20	0.652090	1.997738	1.656206	1.448688
GSADF_{Palladium}	20	1.934810	3.806591	3.159959	2.959097
RtADF_{Platinum}	20	2.656730	0.754335	0.018014	-0.363603
SADF_{Platinum}	20	0.402216	1.997738	1.656206	1.448688
GSADF_{Platinum}	20	3.192100**	3.806591	3.159959	2.959097

Note: Critical values in Table 2 were obtained from the 1000 replicated Monte Carlo simulations for the three tests. *, ** and *** represent 10%, 5% and %1 significance levels, respectively.

The rejection of the null hypothesis that the series do not contain price bubbles for the three tests examining the right tail distributions based on the ADF indicates the existence of rational bubbles in the price series. When the test results were compared with the critical values obtained from the Monte Carlo simulation results, the test results of the single bubble assumption and the GSADF test results measuring multiple bubble formation were different. GSADF test statistics which investigate multiple bubble formations are greater than the critical values calculated with the help of simulation. The null hypothesis that there is no financial bubble is rejected. This result provides evidence of the existence of financial bubbles at different levels of significance in gold, silver and platinum series. Bubble formation dates on precious metals can be seen in detail in Figure 3 below.

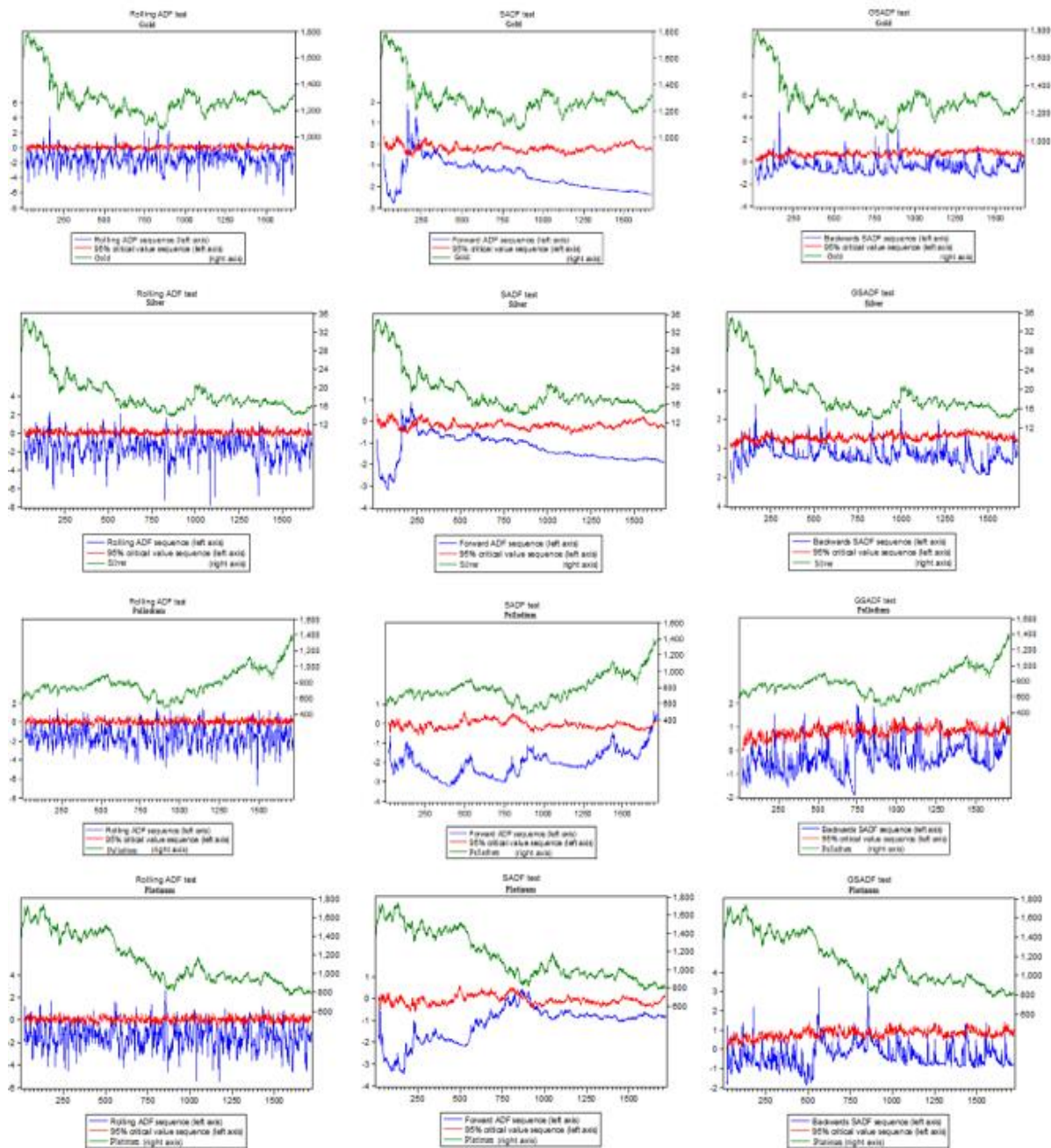


Figure 3. RADF, FADF and BSADF Sequences of Precious Metals

It can be observed from the charts that the bubbles detected in the price series belonging to other precious metals except Palladium occur on similar dates and last for 1 to 7 days. This raises the question of how bubble formation occurring in precious metals can trigger each other. In fact, the investigation of the spillover effect of price bubbles in the precious metal prices is becoming more important in terms of portfolio diversification. After determining the price bubble formations for precious metals, whether there is any return or volatility spillover among these financial assets was investigated with the help of VAR-EGARCH model developed by Koutmos (1996). The multivariate VAR(1)-EGARCH(1,1) model results are presented in Table 3 below.

Table 3. VAR(1)-EGARCH(1,1) Model Results for Return and Volatility Spillover

	Gold	Silver	Palladium	Platinum
Mean Equation				
$\Gamma_{\text{Gold}(-1)}$	-0.133610007*** [-11.63809]	-0.111215395*** [-5.10276]	-0.307103641 *** [-8.81589]	-0.141309483 *** [-3.22499]
$\Gamma_{\text{Silver}(-1)}$	0.021552968 [0.98429]	-0.011254514 [-0.57652]	0.106017609 *** [6.00298]	0.036412841** [2.10875]
$\Gamma_{\text{Palladium}(-1)}$	-0.004363156 [-0.62677]	-0.008726318 [-0.55066]	-0.034274907 [-0.96170]	-0.022490745 [-1.51867]
$\Gamma_{\text{Platinum}(-1)}$	0.079263945*** [8.78376]	0.117520811*** [6.64748]	0.209324110*** [5.77893]	0.088914343*** [4.94034]
Variance Equation				
$\alpha_{i,0}$	-0.007257859*** [-4.36297]	0.001081844 [0.23653]	0.019376715*** [7.44813]	0.021106733*** [6.72792]
$\alpha_{i,1}$	0.044539250*** [6.39760]	-0.001246500 [-0.38789]	0.025561611*** [4.29165]	-0.032102661*** [-5.59208]
$\alpha_{i,2}$	-0.034838902*** [-6.20916]	-0.009615523*** [-3.25711]	-0.009292498** [-2.52922]	0.004948583** [2.34074]
$\alpha_{i,3}$	0.024971455*** [6.09531]	0.012965700*** [2.73013]	0.007910144 [1.36846]	0.008192594*** [5.63097]
$\alpha_{i,4}$	-0.027032613*** [-21.09144]	-0.002835667 [-0.85688]	-0.043959648*** [-13.22030]	-0.008188412*** [-5.54113]
γ_i	0.994999479*** [533.00625]	0.998211917*** [333.81396]	0.996934084*** [402.15296]	0.997097412*** [850.14865]
δ_i	0.672072544*** [5.30339]	1.563822255*** [7.29674]	-0.948155365*** [-5.02897]	0.587294760*** [5.48584]
Conditional Correlation				
	Gold	Silver	Palladium	Platinum
Gold	1			
Silver	0.818577509*** [235.61834]	1		
Palladium	0.325998618*** [29.26362]	0.376558413*** [35.02682]	1	
Platinum	0.667654739*** [106.73912]	0.660123553*** [83.02302]	0.518778221*** [54.07259]	1

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

According to the VAR(1) results of the model established for the return and volatility spillover, it can be seen in the mean equation that there is a multiple spillover between the precious metals returns. When volatility spillover among precious metals in terms of return volatility are examined, it is understood from $\alpha_{i,j}$

parameters that the return volatilities of precious metals are in mutual propagation similar to the return spillover. For all precious metals, γ_i coefficient shows the persistence effect of shock is very high and is close to 1. According to the δ_i parameter representing the asymmetry effect, it is stated that the leverage effect is positive on precious metals other than palladium, that is, the shock effect of positive news is more dominant than negative news.

In the diagnostic test results applied to the model residuals, the model were run robust estimators due to the fact that standardized and square standardized errors include autocorrelation and heteroscedasticity problems. It is understood from the test results of the volatility spillover that the price bubbles seen in precious metals trigger each other. In addition, when the conditional correlation coefficients of the precious metals are examined, it is seen that, among all precious metals, palladium is positively differentiated in terms of portfolio diversification with low correlation between other precious metals.

CONCLUSION

The prices for real or financial assets in financial markets may occur at even higher levels by deviating from market base due to various reasons. This situation, which can be expressed as a financial bubble, can occur rationally and irrationally. Rational bubble is the prices that is traded with the idea that the asset can be sold to someone else profitably although it is known that the price of an asset is higher than the price that should be on the market basis. The burst of these price bubbles has important consequences such as distrust, disappointment, illness, and death due to suicide in markets. The fact that the effects of the financial crisis that started in the USA with the burst of the housing price bubble has spread all over the world and caused a global crisis is an important example. For this reason, it is important to know the existence of financial bubbles, to investigate their causes and to take necessary measures for price stability.

In this study, the existence of price bubbles in gold, silver, platinum and palladium prices in the commodity markets for the period 01.01.2010-19.02.2019 was investigated. RtADF, SADF and GSADF methods were used to determine the formation and burst periods of price bubbles. As a result of the analysis, bubbles were found in gold, silver and platinum prices, whereas no bubbles were found in palladium. In other words, palladium prices are mainly based on the market fundamentals. The results of this study, including the presence of prices bubbles in gold and silver, are consistent with all other studies except Blanchard and Watson (1982) and Bialkowski et al. (2011). To date, no studies regarding price bubbles in the class of precious metals other than gold and silver have been found.

The study also raises the question that gold, silver and platinum prices may have a return and volatility spillover due to the fact that the formation time of the bubbles is very close to each other. Therefore, whether there is any return and volatility spillover among these financial assets is also investigated with the help of VAR-EGARCH model developed by Koutmos (1996). As a result of the study, it was found that there was a multiple spillover between the gold, silver and platinum returns, and thus the price bubbles formed in precious metals triggered each other. The findings related to the volatility spillover among precious metals are also important in terms of considering the effect of this spillover for the investors who provide hedging by precious metals.

These results can be the basis for decisions of investors. In addition, investors involved in the portfolio management activities will be able to consider a multiple spillover among gold, silver and platinum returns. According to the γ_i coefficient obtained by the EGARCH method, new information shocks in the precious metals market show resistance to equilibrium. This result indicates that precious metals markets do not react to information immediately. As a conclusion, it can be said that the markets mentioned are not effective. That is, they offer opportunities for speculative gains.

In future studies, price bubbles for different assets in commodity or other markets and the effect of control variables such as economic growth, interest rates, etc., on the formation of such bubbles may be investigated. Besides, the existence of bubbles in asset prices may be investigated by different methods such as Markov regime switching ADF method.

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