Testing Explosive Bubble for Eurozone Exchange Rate in the COVID-19 Outbreak: Evidence from Recursive Right-Tailed Tests

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Abstract

This paper investigates the presence of explosive bubbles in financial markets using daily data (5-day weeks) of the closing rate of EUR/USD exchange in the COVID-19 outbreak, covering the period from December 2, 2019 to December 4, 2020. The bubble behavior in the closing rate of EUR/USD exchange is measured by two distinct right-tailed testing procedures. In this vein, the Supremum Augmented Dickey-Fuller (SADF) test developed by Phillips et al. (2011) and the Generalized Supremum Augmented Dickey-Fuller (GSADF) test developed by Phillips et al. (2015) are used to identify multiple bubble periods. The empirical findings imply that positive bubbles are a common feature of the closing rate of EUR/USD exchange in the COVID-19 outbreak. As a critical year, 2020 is identified to point out the importance of explosive bubble behavior, after which estimated statistics by two types of unit-root test procedures provide evidence of ongoing financial instability.

Keywords: *Exchange Rate, Bubble Behavior, Financial Instability, COVID-19, Right-Tailed Test*

JEL Classification: *C22, C51, G01*

1. Introduction

The world economy faced a severe financial crisis in 2007, which had been led by the collapse of Lehman Brothers in the US. However, this is neither the first nor the last in which the financial markets have been confronted with several bubbles throughout time across different countries and regions. In that vein, the possibility of occurrence of the financial bubbles has led several countries to make provision for alleviating their impacts of potential harms on the economic system. However, the problems that the financial markets have to deal with are essentially very far away from being solved due to the fact that financial assets still attract different kinds of investors even though the bubbles may negatively affect individuals' financial profits. Therefore, the demand-led financial motives for several assets in financial markets lead the prices of those assets to skyrocket in a very short time; and thus, cause the emergence of financial bubbles. However, the divergence from the equilibrium point between demand and supply in the asset market due to excess demand for financial instruments eventually results in the burst of a financial

Original Research Article
Received: 18.12.2020
Accepted: 29.05.2021

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bubble. The collapse of the financial system to a large extent caused by the bursting of the bubble has been contagious among the countries and has led to a considerable amount of recovery attempts by governments together with several global organizations to avoid the contamination (Ahmed et al., 2016). As the final shock in financial markets, which affects all the economies, particularly pointed out the importance of financial instabilities from being protected to the collapse of the real sector (Afşar et al., 2019).

The dramatic changes in the value of the currencies during the unexpected moments allow for unprecedented movements of asset sales back in just a short time. In particular, the markets that have very fragile foundations may not have a chance to recover their ongoing problems where several economies from the developing region encounter outflowing of a huge amount of foreign assets abroad. Since the capital outflows are considered as undesirable for host countries, leaving money from an economy at an extremely high rate plays an important role about foreign imbalances and financial crises that may originate from increasing speculative motives devoted to an excess demand towards foreign assets. In that sense, the foreign exchange markets can be considered as the focal point in which the financial problems can easily be identified by way of analyzing the current movements of foreign capital subject to the socio-economic structure. In addition, the foreign exchange markets are important for the reason that the financial fluctuations resulting from the capital movements are reflected in domestic prices. Hence the bubbles become a threat for the financial markets if the domestic price level exceeds a certain benchmark level in which several economic indicators depend on price movements. This may be thus explained as one of the major reasons why the real economic indicators get worse following the burst of asset bubbles. Given the financial market bubbles of crucial importance in exchange rate movements, a bulk of studies have conjectured that the exchange rates were driven by speculative motives at the beginning of its outbreak.

Even though the speculative motives substantially lead investors to invest in risky assets for getting more financial profits, the determination of exchange rate bubbles is still puzzling economists as well as the financial market participants. Besides the existence of speculative bubbles in financial markets have been a longstanding problem under the debate of many scholars, the assumptions behind the orientation towards capturing more profits in those markets are far away from being agreed in the theoretical context. An undeniably high mass of economists still advocates the theoretical and empirical validity of rational expectations together with the rational behavior of economic agents which is based on the knowledge that the pricing of an asset is determined as regards to "market fundamentals" of given assets (Wu, 1995: 27). So, deviations of an asset's price from its optimum level determined by its market fundamentals are important for detecting the emergence of bubbles in financial markets, which is exacerbated by irrationality. On the other hand, the second pillar of studies implies that self-fulfilling rumors of investors in financial markets can affect the pricing dynamics of assets as well. In that vein, they are often assumed as the reasons that lead to the occurrence of asset bubbles.

However, the historical investigation on the assumption of irrationality shows that the discrepancies between an asset's price and its actual value does not necessarily be understood from the standpoint of rational expectations. On the contrary, the structural ingredients of occurrence of asset bubbles should also be undertaken by way of looking at different phenomena; and thereby, reflecting mixed results (Shiller, 1978; Blanchard, 1979; Obstfeld and Rogoff, 1983; Diba and Grossman, 1988a; Gilles and LeRoy, 1992).

In this paper, considering the presence of asset bubbles in financial markets, the detection of its possible occurrence in the COVID-19 outbreak will be examined by way of using closing EUR/USD exchange rate for the Eurozone countries for the period from December 2, 2019 to December 4, 2020. The remainder of the paper is organized into five sections. Section 2 points to the importance of a bubble in financial markets by looking at the causal linkages among several determinants. Section 3 presents the details of some theoretical approaches on exchange rate bubbles along with the literature review. Section 4 explains the data set and the empirical methodology. Section 5 reports the empirical findings. Section 6 summarizes the core results and concludes.

2. Speculative Bubbles and Financial Markets: The Causal Linkage

The major way to express the importance of bubbles that may occur in financial markets is to understand the ongoing formation of the real sector. In other words, the interdependency of different sectors in a globalized world requires to ascertain complex features of a causal relationship between financial markets and the real economy. However, the gap between the real economy and the financial markets is rarely assumed as clear as possible that some people thought. In essence, the presence of the negative effects of volatility and the sharp increases in asset prices lead many economists and analysts to consider the magnitude of bubbles in financial markets, which of those recognize the potential of their impacts on the real economy. In that vein, the bubbles are typically associated with sharp increases in prices of financial instruments resulting in panics and crashes (Kindleberger and Aliber, 2005). The common vision on the way that leads to the emergence of bubbles and thereby financial crises depends on an increasing gap between the actual and current prices of financial instruments. Indeed, the speculative motives of investors encourage them to demand more towards the ownership of several kinds of assets in which they become conditioned to sell those assets at higher prices. The breaking point is that the bubbles emerge in financial markets when manias for the case of reliance towards an absolute increase in prices of different financial instruments are supposed to discern that it comes to an end. Indeed, this is the fact that a substantial amount of investment on financial assets swiftly reduce in parallel to a decrease in demand for those assets and thereby their prices.

The causal linkage between financial markets and the real economy emerges at this point. Since the asset bubbles emerge in terms of their prices along with bankruptcies and credit defaults, the real investment may confront with serious disadvantages resulting in a decrease of employment, and investment opportunities. As a reflection of this, market participations, as well as policymakers, act to prevent the collapse of financial markets (Grover and Grover, 2014). The major reason that the economic actors have a part in counteracting against the occurrence of financial crises is that the financial instability may tend to cause serious socio-economic and political problems in world economies.

The literature on the history of financial crises and the burst of financial bubbles specifies that concern by arguing that the asset price deflation following the resolution of speculative mania cause the economic structure to be seriously affected throughout a particular period of time (Malkiel, 2010). Therefore, the investigation of the relationship between speculation and resilience in resource-based communities (i.e., boomtowns) susceptible to economic swings (boom/bust) becomes more charming in the relevant literature (Deacon et al, 2018). In that sense, the mechanisms behind the financial bubbles can be intuitively categorized into two parts. As Sornette and Cauwels (2014: 5) state that "during bubbles, prices move away from their so-called fundamental value; where, during positive bubbles, there is excessive demand and, during negative bubbles, there is disproportionate selling". Therefore, when the bubbles burst, prices suddenly decrease in parallel to the case in which the rate of defaults and foreclosures skyrocketed in the real economy. During the fast price appreciation of a bubble phase where the speculative motive exceeds the precautionary motive for "…the object of securing profit from knowing better than the market what the future will bring forth…" (Keynes, 1936: 170), the oscillations are subjected to an ever-increasing frequency, implying that the inertia of investors when reevaluating their expectation decreases (Sornette and Cauwels, 2014: 17). However, together with a decrease in price expectations to rise endlessly and thereby the reduction of demand towards such assets lead investors to get rid of those assets by trying to sell them in financial markets. Since the price deflation in financial markets becomes clear, it leads to an increase in transactions in over-the-counter markets, which also exacerbates the potential problems in an economic environment. Therefore, the burst of bubbles in financial markets primarily affects the growth rate of an economy and future projections of current investment. If the financial markets in countries where a certain level of financial development is not provided, the effects of bubble bursts become more severe in terms of economic growth.

Moreover, this research implies that the financial markets are inherently unstable as Minsky (1992) developed to show that speculative and Ponzi-type finance became the driving force for asset demand behavior of individuals in unregulated or loosely regulated financial markets. Although they are assumed as playing an important role in economic functioning such as pricing, providing an efficient allocation of capital, and enabling risk diversification, the unfettered degree of financial globalization and the "financialization of daily life" (Martin, 2002) exacerbate the financial cycles characterized by the rapid escalation of asset prices and thus induce dramatic fluctuations in financial asset prices and business cycles along with the occurrence of more severe bursting of the bubbles in financial markets. Hence, each problem augments the ways that lead to the emergence of several crises in different platforms such as the banking sector and foreign exchange markets. The next part will be based on the investigation of theoretical approaches for the occurrence of exchange rate bubbles and of the relevant literature.

3. Theoretical Approaches and Literature Review

To categorize the trajectory of exchange rate movements, one should formulate the theoretical framework to account for the occurrence of large deviations, as well as for some mean-reversal behavior (Maldonado et al., 2012: 1034). Moreover, the asset nature of exchange rate stocks, forward exchange contracts, and foreign exchange deposits should be well-designed in terms of analyzing the risk-based effects of assets which are prone to speculative motives. In addition, it necessitates the deductibility of its role in pricing tradeable goods relative to non-tradable ones (Maldonado et al., 2012: 1034).

The theoretical models on the determination of exchange rate bubbles are several in the literature. However, the distinctive features of each model are based on their data selection process, which lead them to grasp the heterogeneous dynamics of exchange rate bubbles. One group of studies focalizes the structural system of equations to detect the exchange rate movements as part of two distinct components: (i) the *fundamental value* and (ii) the *bubble*. For instance, Tirole (1985) and Blanchard and Fisher (1989) develop macroeconomic models to define the reasons behind the occurrence of bubbles. In addition, the other group of research considers the stochastic specification of the bubble. In that vein, the major research topics in which they investigate the differences in terms of specific factors: (i) the ways that lead to the disappearance of bubbles (Obstfeld and Rogoff, 1983; Engsted, 1993), (ii) the collapsing process of bubbles in case of exogenous probability (Blanchard, 1979; Blanchard and Watson, 1982), and (iii) the inception and survival of bubbles (Diba and Grossman, 1988a).

Considering these theoretical classifications to detect the bubble formation over time, some historical investigations can be summarized to understand the bubbles in practice. For instance, Evans (1986) benefits from a non-parametric strategy that deems the possibility of several bubble bursts for the sterling-dollar exchange rate and finds evidence of a negative bubble in excess return to holding sterling rather than dollar assets during 1981 – 1984. Meese (1986) provides mixed evidence of asset market bubbles or extraneous factors in exchange markets, using a monthly monetary model of exchange rates, and rejects the tests of the no-bubbles hypothesis regards to dollar/deutsche mark and the dollar/pound exchange rates over the period 1973 – 1982. West (1987) follows a parametric method and rejects the joint hypothesis that no bubbles occur in the Standard & Poor's 500 index and the Dow Jones index over the period 1871–1980 and 1928–1978, respectively. Diba and Grossman (1988b) analyze the existence of bubbles based on unit-root testing procedures and cointegration analysis for the stock price and the dividends. The empirical findings indicate that the existence of an explosive rational bubble in prices is not robust in a statistical framework. In addition to these early phase analyses to test the presence of bubbles in financial markets, a bulk of studies were also investigated the same topic from different perspectives. Some of them can be ranged as follows: Shiller, 1981; Hart and Kreps, 1986; Rappoport and White, 1994; Hall et al., 1999; Nasseh and Strauss, 2004; Maldonado et al., 2012; Geuder et al., 2019.

However, many of these estimates intrinsically assume that the potential occurrence of bubbles has an upward tendency until the structural dynamics exogenously change in time. Indeed, this restrictive assumption can be relaxed by employing a regime-switching model for the bubble. Therefore, two alternative dynamics of the bubble size should be designed by economic agents and the possibility of regime change should be incorporated into their expectations (Maldonado et al., 2012: 1034). Following this background, the bubbles have two characteristics. On the one hand, it will be collapsing with decreasing expected size. On the other hand, it will be survived with increasing expected size. Each formulation leads to the context of literature to change from a different perspective. For example, Evans (1991) states that bubbles collapse in regular periods, depending on their size. Besides the estimates of Evans (1991), which show that the bubble regime is observable, Van Norden and Schaller (1993) suppose that it is not, where the bubble regime is determined by a non-observable stochastic binary variable together with the assumption that the bubble size affects the probability of occurrence. Van Norden (1996) also extends this formulation by looking at the speculative bubble mechanisms in the exchange rate between the US dollar and three other major currencies and concludes that there is mixed evidence for the occurrence of regime-switching bubbles. The other studies based on the regime-switching formulation in bubbles find similar results as Van Norden (1996) reveals (e.g., Funke et al., 1994; Driffill and Sola, 1998; Roche, 2001; Brooks and Katsaris, 2005). Finally, a related body of literature assesses whether the Markov-Switching models are more reliable based on the estimation of speculative bubbles in financial markets (Hamilton, 1994; Hall et al., 1999; Liu et al., 2012; Lucey and O'Connor, 2013; Shi, 2010, 2013; Das, 2017; Balcombe and Fraser, 2017).

4. Data and Empirical Priors

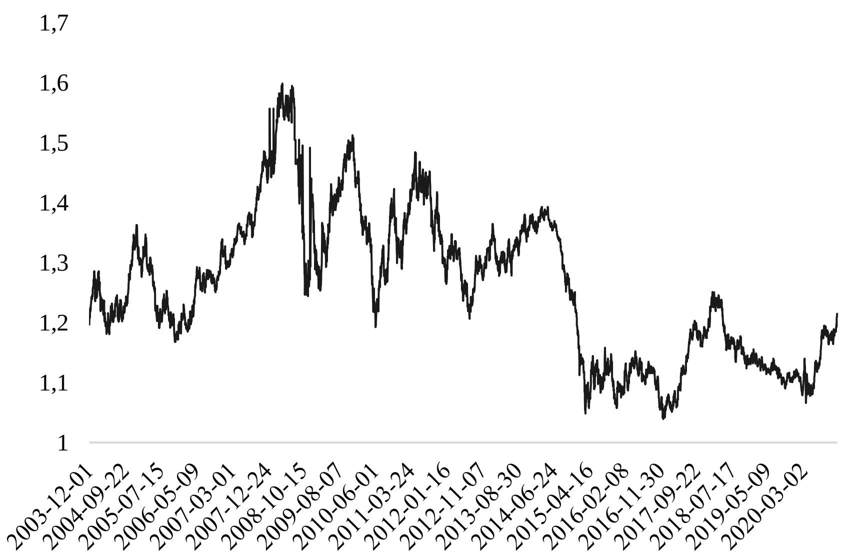
4.1 Data

The data of this paper covers the daily data (5-day weeks) of the closing rate of EUR/USD exchange, $E_{€/\$}$, during the period from December 2, 2019 until December 4, 2020 as obtained from Yahoo Finance. As the exchange rates are available five days a week for certain hours, the data is collected for all available days and corresponds to a total of T = 265 days. The empirical method is tested with the statistical software EViews version 10. The exchange rates are estimated in natural forms. Table 1 reports the key summary statistics for closing rate of EUR/USD exchange. The minimum $E_{€/\$}$ is 1.0657, whereas the maximum $E_{€/\$}$ of 1.2146 shows 18.66% depreciation of the euro against the dollar. This fluctuation of the euro/dollar exchange rate in the sample introduces the possibility of a bubble burst in the Eurozone. The closing rate of EUR/USD exchange is positively skewed. In addition, the kurtosis value of closing rate of EUR/USD exchange is lower than 2, indicating that it is platykurtic. Therefore, the distribution produces fewer extreme outliers such as uniform distribution than does normal distribution. As expected, the Jarque-Bera test rejects the null hypothesis for the Gaussian distribution at a significance level of 1%. Finally, Figure 1 shows the historical movements of EUR/USD exchange rate over the sample period. The closing rate of EUR/USD exchange series is not stationary, as confirmed by Figure 1. Also, as anticipated, the null hypothesis of nonstationary is rejected for the augmented Dickey-Fuller (ADF) test, meaning that the series have order one *I* (1) process.

Table 1. Descriptive Statistics

	Minimum	**Maximum**	**Mean**	**Median**	**Skewness**	**Kurtosis**	**Jarque-Bera**
Close	1.0657	1.2146	1.1338	1.1226	0.2276	1.5837	24.4348

Figure 1. Historical Movements of EUR/USD Exchange rate



Source: Yahoo Finance

4.2 Empirical Methodology

The core method that the paper uses in the empirical analysis is based on a test procedure developed by Phillips et al. (2011; PWY hereafter), which is right-tailed versions of the traditional Augmented Dickey-Fuller (ADF) test with parameter δ.

The statistics test the unit-roots of an explosive root:

H_0: δ = 1

H_1: δ ≠ 1

which means that the rejection of null hypothesis (H_0) against its alternative (H_1) refers to an explosive root in series. In that sense, the rejection of H_0 points to the case that the bubbles are statistically prevailing. The PWY procedure includes two types of statistics: (i) a recursive supremum ADF (SADF) and (ii) a generalized supremum ADF (GSADF). The methodological representation can be shown in Equations (1) and (2) as follows:

$$SADF\ (r_0) = sup_{r_2 \epsilon [r_o,1]}\{ADF_0^{r_2}\} \tag{1}$$

$$GSADF\ (r_0) = sup_{r_2 \epsilon [r_o,1];\, r_1 \epsilon [0, r_2 - r_1]}\{ADF_{r_1}^{r_2}\} \tag{2}$$

where $r_1, r_2 \epsilon [0,1]$ are a series of subsamples. Relative to the SADF statistic, the GSADF statistic is more efficient and provides robust results since its flexibility in window widths is much higher and includes more fractions of the overall sample.

The detection of an explosive root also extends to the presence of one or multiple bubble periods. The above strategy further developed by Phillips et al. (2015; PSY hereafter), which is based on a backward supremum ADF (BSADF) test, represents a double recursive method:

$$BSADF_{(r_2)}(r_0) = sup_{r_1 \epsilon [0, r_2 - r_0]}\{ADF_{r_1}^{r_2}\} \tag{3}$$

Indeed, the BSADF testing procedure benefits from the SADF and GSADF statistics, respectively. This newly updated procedure developed by Phillips et al. (2015) divides the current series into two periods in which the bubbles start in $\hat{r}_{i,b}$ and end in $\hat{r}_{i,e}$, given in Equations (4) and (5), respectively:

$$\hat{r}_{i,b} = inf_{r_2 \epsilon [r_0,1]}\ \{r_2 : BSADF_{r_2}(r_0) > scv_{r_2}^{\alpha_T}\} \tag{4}$$

$$\hat{r}_{i,e} = inf_{r_2 \epsilon \left[\hat{r}_{i,b} + \frac{\gamma \log(T)}{T}, 1\right]}\ \{r_2 : BSADF_{r_2}(r_0) < scv_{r_2}^{\alpha_T}\} \tag{5}$$

The recursive rolling window of Phillips et al. (2015) was also extended by Phillips and Shi (2018, 2020) for detecting the multiple bubbles. Each observation from the sample ranges in an interval between r_0 and 1 for the PSY testing procedure, where $r_0 = 0.01 + 1.8/\sqrt{T}$.

Under the null hypothesis of $\rho = 0$, the regression analysis is based on the estimates representing in Equation (6):

$$\Delta y_t = \mu + \delta y_{t-1} + \sum_{i=1}^{p} ø_i \Delta y_{t-i} + \varepsilon_t \tag{6}$$

By using Equation (6), the multiple bubbles for the period determination can be evaluated into two dates matching as the *exuberance date* and the *collapse date*. On the one hand, the exuberance date implies that the PSY test statistic is initially higher than its critical value in which the first episode ends. On the other hand, the collapse date indicates that the supremum test statistic drops below its essential value in which the second episode is completed. Let the episode is unitary for the sample arising from r_e and r_f. Following the Phillips and Shi (2018; 2020) procedure, Equations (7) and (8) can be conducted for the determination of estimated periods and termination dates:

$$\hat{r}_e = inf_{r\epsilon[r_0,1]} \{r: PSY_r(r_0) > cv_r(\beta_T)\} \quad (7)$$

$$\hat{r}_f = inf_{r\epsilon[\hat{r}_e,1]} \{r: PSY_r(r_0) < cv_r(\beta_T)\} \quad (8)$$

where $cv_r(\beta_T)$ represents the quantile of the distribution of the $PSY_r(r_0)$ of Equation (3).

5. Empirical Findings

Table 2 reports the results of SADF and GSADF test statistics for the closing euro/dollar exchange rate with 95% critical values obtained by the Monte Carlo simulation using the EViews 10 package. Following Phillips et al. (2015), initial window width is measured as $r_0 = 0.01 + 1.8/\sqrt{265} \approx 0.121$, which yields 0.121*265 ≈ 32. So, the initial window width includes 32 observations. The right-tailed unit-root test statistics show that the null hypothesis is rejected at the 5% significance level for the SADF test and the 1% significance level for the GSADF test in favor of the alternative hypothesis, representing that there is at least one explosive unit in the series. In other words, bubble behavior in at least one subperiod of the EUR/USD exchange rate series can be assumed for the COVID-19 outbreak. This leads us to ask, for which subperiods this assumption holds.

Table 2. Closing Rate of EUR/USD Exchange SADF and GSADF Statistics

	Test Statistic	*Critical Values*		
Confidence Level		90%	95%	99%
SADF	0.72	0.21	0.43	1.14
GSADF	2.43	0.99	1.21	1.74

Note: *The critical values are measured by Monte Carlo simulation using EViews software version 10. The test statistic for SADF exceeds the critical values at the 95% confidence level and the test statistic for GSADF exceeds the critical values at the 99% confidence level. The sample period is from December 2, 2019 to December 4, 2020.*

To assess the background of this question, the empirical strategy tends to analyze the backward SADF sequence and their corresponding critical values for a 95% confidence level as represented in Figures 2 and 3 for SADF and GSADF testing procedures, respectively. On the one hand, the graphical output in Figure 2 for the SADF test shows that three subperiods containing bubble behavior. All of these bubble periods are dated in 2020. The initial one starts at the end of February and ends in the second week of March. The following period ranges between the middle of July and at the end of July. The third period starts at the beginning of August and ends in the middle of August. On the other hand, the graphical representation in Figure 3 for the GSADF test indicates that four subperiods containing bubble behavior. In 2020, the bubble period ranges from February to March, a short period in time from the middle of March to the end of March, the third period from May to June, and a fourth period range from July to August. These findings mostly correspond with the literature assuming that the positive bubbles are likely to occur over time. The distinctive feature of this paper is to extend this explosive bubble behavior in exchange rate by looking at Eurozone and to assess its statistical significance in the COVID-19 outbreak for the period between December 2, 2019 and December 4, 2020 in terms of 265 observations and 32 initial window width.

Figure 2. The SADF Test Results

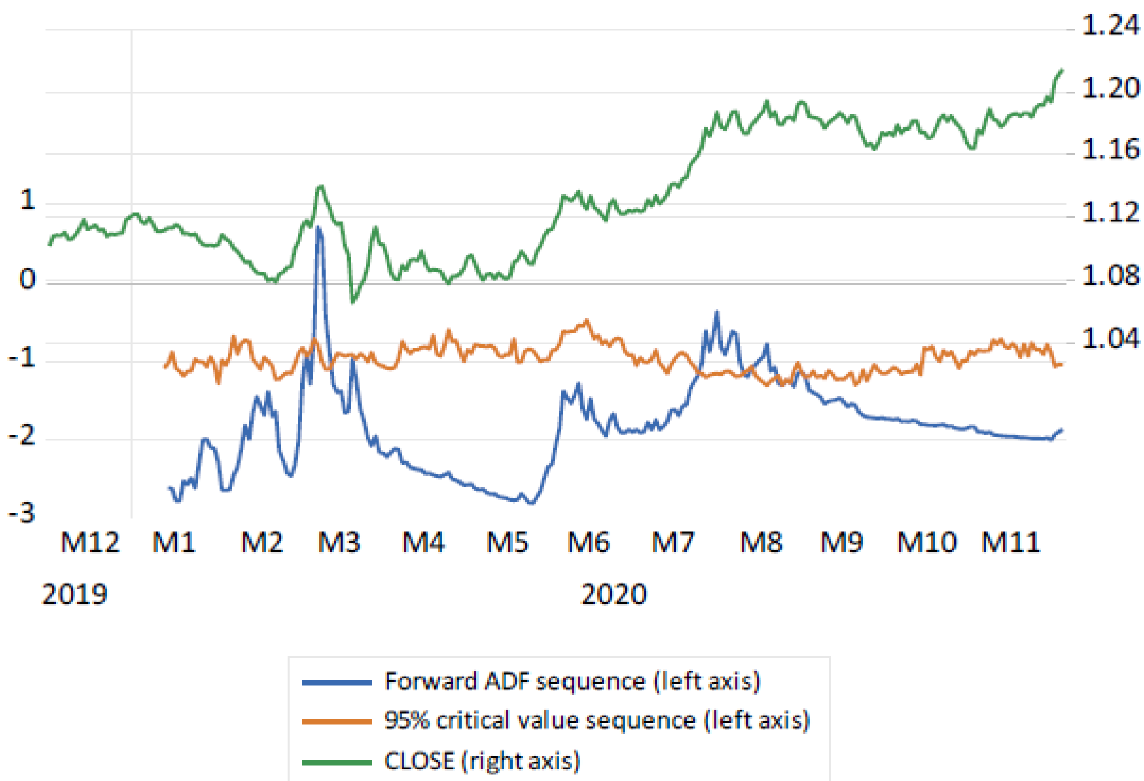
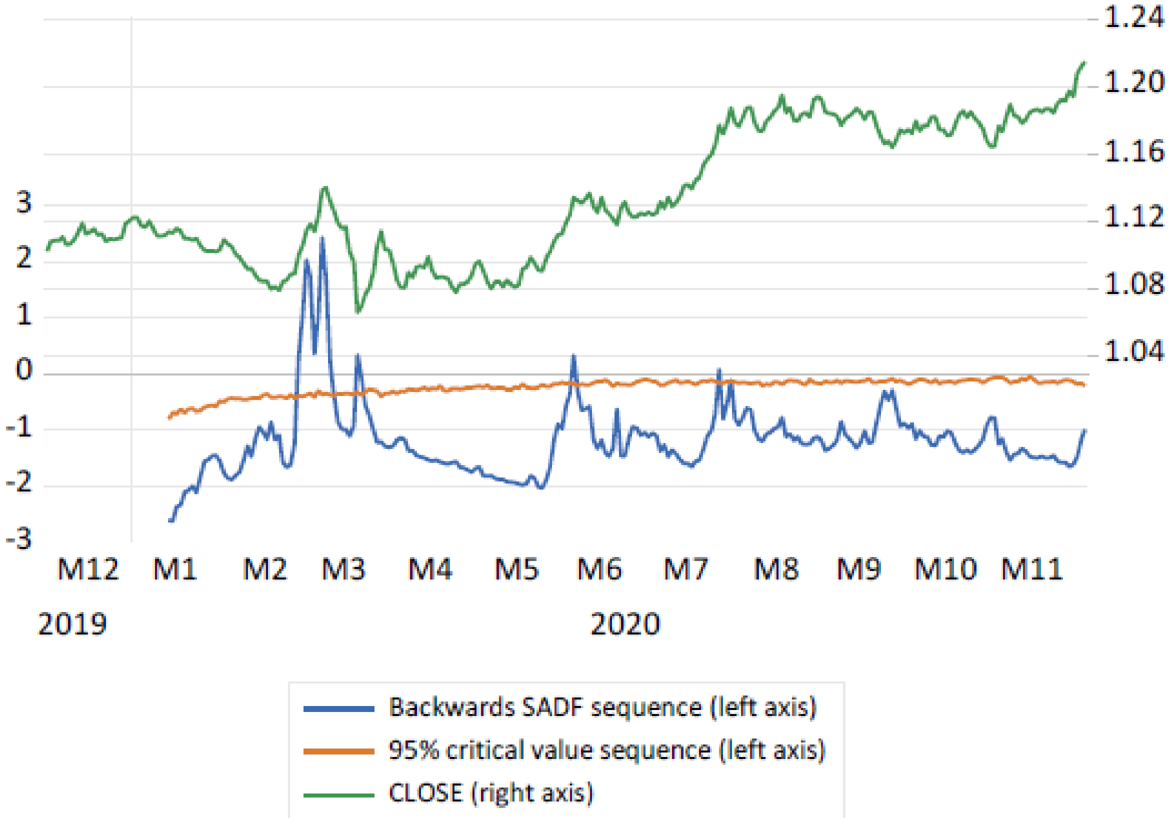


Figure 3. The GSADF Test Results



6. Concluding Remarks

In this study, the Monte Carlo simulation of Phillips et al. (2011, 2015) is used to identify the explosive bubble behavior in the closing rate of EUR/USD exchange from December 2, 2019 to December 4, 2020. The major aim is to assess whether the explosive bubbles in EUR/USD exchange rate are likely to occur in the COVID-19 outbreak. The empirical findings based on right-tailed unit-root testing procedures, covering SADF and GSADF, confirm the existence of frequent bubble periods in the closing rate of EUR/USD exchange. A natural question that arises from those results depends on which factors caused these episodes of bubble behavior. In other words, the results have also some practical implications. Given the flatting the spread of COVID-19 using lockdowns, a surging unemployment level, skyrocketing level of youth unemployment, a lower level of industrial production, a decrease in investment spending, and increasing demand for speculative motives along with an increasing degree of Ponzi-type finance may have significantly affected the closing rate of EUR/USD exchange across the Eurozone over the COVID-19 outbreak. Those issues are also instructive for governments, economic agents, and policymakers who have to make decisions on financial instability measures. Future studies will be based on the analysis to test whether the above findings are significant over the long-run historical period across the Eurozone.

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