Hacettepe University Graduate School Of Social Sciences

Department of Economics

# AN EMPIRICAL INVESTIGATION OF RATIONAL BUBBLES IN US DOLLAR-TURKISH LIRA EXCHANGE RATE BY MEANS OF CURRENCY DERIVATIVE MARKET

İrem KAYA

Master's Thesis

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# ACCEPTANCE AND APPROVAL

The jury finds that İrem KAYA has on the date of 06.06.2023 successfully passed the defense examination and approves her master's thesis titled "An Empirical Investigation of Rational Bubbles in US Dollar-Turkish Lira Exchange Rate By Means of Currency Derivative Market".

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# ABSTRACT

KAYA, İrem. *An Empirical Investigation of Rational Bubbles in US Dollar-Turkish Lira Exchange Rate By Means of Currency Derivative Market,* Master's Thesis, Ankara, 2023.

This study aims to investigate whether USD/TRY exchange rate exhibits any rational 'speculative' bubble formations over the period 2001-2022. As a rational bubble in any asset price is defined as consistent deviations of prices from its fundamental value, testing for bubbles using some statistical techniques might be straightforward under the assumption that model specification for fundamentals is correct. However, given parameter and model uncertainties about model specification for fundamentals, one can never be certain about the results of the tests based on fundamental specifications to conclude the presence of rational bubbles or model misspecification because rejecting the null hypothesis might point to either or both of these cases. Recently, the study by Pavlidis, Paya, and Pell (2017) propose a method for testing rational bubbles, which they argue, does not depend on model specification for fundamentals. Their method simply looks at the spot-forward rate deviations. One can see if such deviations are explosive such that periodically collapsing bubbles are present by means of right-tailed unit root tests (GSADF test) developed by Phillips et al. (2015). This study adopts the method of Pavlidis et al. (2017) by applying GSADF tests to differences of spot-forward USD/TRY exchange rates in order to investigate the existence of rational bubble formations in USD/TRY exchange rate. We find that although the spot rate itself presents excessive behavior, especially after 2014, spot-forward differentials are not explosive, meaning that there is no evidence of rational 'speculative' bubbles in USD/TRY exchange rate over the sample period.

**Keywords**

Speculative bubbles, GSADF test, exchange rates, explosive dynamics, forward exchange rate

# ÖZET

KAYA, İrem. *Döviz Kuru Türev Piyasası Aracılığı İle ABD Doları-Türk Lirası Döviz Kurunda Rasyonel Balon Tespiti İçin Ampirik Bir İnceleme*, Yüksek Lisans Tezi, Ankara, 2023.

Bu çalışma, 2001-2022 dönemi arasında USD/TRY döviz kuru fiyatında rasyonel 'spekülatif' balon oluşumunun varlığını araştırmayı amaçlamaktadır. Rasyonel 'spekülatif' balon, herhangi bir varlık fiyatının temel değerinden daimi bir süreyle ayrışması olarak tanımlanır. Temel değerlere ilişkin model spesifikasyonunun doğru olduğu varsayımı altında, bazı istatistiksel testler kullanılarak bu balonları test etmek oldukça kolaydır. Ancak, model spesifikasyonunda parametre ve model belirsizliği göz önüne alındığında, balonların varlığı veya model spesifikasyon hatası hakkında kesin bir sonuca ulaşmak güçtür, çünkü sıfır hipotezinin reddedilmesi her iki duruma da işaret edebilir. Yakın zamanda Pavlidis, Paya ve Pell (2017) tarafından yapılan bir çalışma, temel değerlere ilişkin model spesifikasyonuna bağlı olmayan bir yöntem önermektedir. Bu yöntem esasen spot-forward kur arasındaki ayrışmalara bakmaktadır. Bu sapmaların patlayıcı özelliklerinin olup olmadığı ve periyodik olarak çöken balonların varlığı, Phillips vd. (2015) tarafından geliştirilen sağ kuyruklu birim kök testi (GSADF testi) yardımıyla görülebilmektedir. Bu çalışma, Pavlidis ve arkadaşlarının yöntemini benimseyerek, spot-forward USD/TRY döviz kuru farklılıklarına GSADF testleri uygulayarak, USD/TRY döviz kuru üzerindeki rasyonel balon oluşumlarının varlığını araştırmaktadır. Sonuç olarak, spot kurun kendisi özellikle 2014'ten sonra aşırı davranış sergilemiş olsa da, spot-forward kurları arasındaki fark patlayıcı bir karakteristik göstermemektedir. Başka bir deyişle, incelenen dönemlerda USD/TRY döviz kuru için rasyonel "spekülatif" balonlara dair herhangi bir kanıt bulunmamaktadır.

**Anahtar Kelimeler**

Spekülatif balonlar, GSADF test, döviz kurları, patlayıcı dinamikler, vadeli döviz kuru

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# ABBREVIATIONS

| | |
|---|---|
| ADF | Augmented Dickey-Fuller |
| BRICS | Brasil, Russia, India, China, South Africa |
| CBRT | Central Bank of the Republic of Turkey |
| CNY | Chinese Yuan |
| CPI | Consumer Price Index |
| EMH | Efficient Market Hypothesis |
| EUR | Euro |
| FED | Federal Reserve |
| FX | Foreign Exchange |
| GBP | British Pound |
| GSADF | Generalized Sup Augmented Dickey Fuller |
| IMF | International Monetary Fund |
| INR | Indian Rupee |
| JPY | Japanese Yen |
| KZT | Kazakhstan Tenge |
| PP | Phillips-Perron |
| PPI | Producer Price Index |
| RMB | Chinese Renminbi |
| RUB | Russian Ruble |
| SADF | Sup Augmented Dickey Fuller |
| TRY | Turkish lira |
| USD | United States Dollar |

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# INTRODUCTION

Markets have cycles, where asset prices can go up and down. However, it is important to recognize the distinction between the usual ups and downs and the extreme highs and lows since these extreme movements have the potential to evolve into bubbles. Understanding when and why such extreme movements occur is critical for both investors and policymakers, especially in today's world where economies are increasingly interconnected, and a problem in one market can spread and has adverse impacts on other markets.

Sudden and prolonged rises in asset prices have intrigued economists in international finance for a long time. Some economists believe that bubbles are a result of market irrationality and therefore, they do not accept the concept of bubbles. They argue that the true value of an asset is determined by market fundamentals, which is known as the fundamental value of an asset. Accordingly, any deviations from fundamental value are temporary and quickly corrected by the market. This perspective stems from the efficient market theory developed by Eugene F. Fama. The theory suggests that it is impossible to consistently achieve higher returns than the overall market average since all relevant information is already reflected in prices (Fama, 2014). However, sudden and rapid changes in markets challenge Fama's theory and raise doubts about its validity because such changes cannot be easily explained by market fundamentals alone (Roehner, 2002; de Oliveira & Almeida, 2014).

On the other hand, economists, who acknowledge the presence of something that causes persistent and substantial changes in prices, emphasize the importance of finding a logical economic explanation (Wöckl, 2019). Their studies on the dynamic of prices reveal that it is theoretically possible for bubbles to occur within the framework of the efficient market hypothesis (EMH). Based on this, asset prices consist of not only a fundamental component but also a bubble component that can help explain the unusual dynamics in prices (Miao, 2014). This made the topic more appealing and provided new insights into the nature of market behavior, the rational bubble theory. Rational bubbles occur when an asset's price rises significantly above its fundamental value, often driven by speculation or investor hype. Such bubbles are also known as speculative bubbles, asset price bubbles, financial bubbles, or economic bubbles (Wöckl, 2019).

While the rise in prices continues for some time and deviates from economic fundamentals, the bubble starts and inflates. In consequence, the inflating bubble bursts, and prices then subsequently collapse (Sornette & Cauwels, 2014). This poses a real threat to financial markets and thus the whole economy. Given their severe consequences, the need for detection emerges in order to avoid unwanted results for the economy of a country and the world economy as a whole. Accordingly, attention has turned to developing methods for detecting bubbles and investigating their behaviors. However, some difficulties arise when designing appropriate tests for bubbles. For instance, given parameter and model uncertainty about model specification for fundamentals, one can never be certain about the results from the tests based on fundamental specifications. Rejecting the null hypothesis might point to the presence of a bubble, model misspecification, or even both of these cases. To put differently, alternative market fundamentals could explain explosive behavior in prices but are unknown to the researcher or not included in the model (Otero et al., 2021). In that case, one may mistakenly claim that bubbles exist (Hamilton & Whiteman, 1985; Flood et al., 1994; Gurkaynak, 2008).

To handle model specification problem, Pavlidis et al. (2017) offer a theoretical model that does not take a set of observed market fundamentals directly into account. This alternative method is straightforward, which allows us to test the null of ‘no rational bubble’ by examining the deviations of future spot from forward (futures) rates. Explosive behavior in spot-forward rates is viewed as rational bubbles, which can be investigated by several statistical techniques such as unit root or cointegration tests. However, these tests cannot perform well if there is more than a single bubble (periodically collapsing multiple bubbles) in the series (Gurkaynak, 2008).

The recently developed recursive right-tailed unit root test, called generalized supremum augmented Dickey-Fuller (GSADF), put forward by Phillips et al. (2015a) enables us to detect periodically collapsing multiple bubbles. GSADF test technique can locate more than one episode of bubbles in a sample period and the origination and collapse dates of them by eliminating the impact of collapsing time periods (Arshanapalli & Nelson, 2016). This test has been widely used in numerous bubble studies (e.g., housing market, foreign exchange market, equity market).

This study adopts the method of Pavlidis et al. (2017) by applying GSADF tests to differences of spot-forward USD/TRY exchange rates, in order to investigate the existence of rational bubble formations in USD/TRY exchange rate. Although there are empirical studies investigating bubble formation in USD/TRY or EUR/TRY exchange rates, they apply GSADF tests to spot rate itself (Korkmaz et al., 2016; Korkmaz, 2018; Afsar et al., 2019; Gulcan et al. 2021; Gok, 2021; Isildak, 2022; Samirkas, 2022; Ozdemir, 2022; Yildirim et al., 2022; Karcioglu and Ozcan, 2023). They document that spot rates exhibit explosive behavior and view this result as the presence of bubbles. However, explosive behavior in spot rates is not a sufficient condition to identify rational 'speculative' bubbles in asset prices (Bettendorf & Chen, 2013). It is essential to study rational bubbles in nominal exchange rates by taking into account underlying fundamentals, if known, or spot-forward differentials since fundamentals are uncertain.

Given these considerations, this thesis follows the lead of the study by Pavlidis et al. (2017) that utilizes information on the expectations of investors about economic fundamentals from the forward market. Accordingly, the GSADF test is performed by using monthly US dollar - Turkish lira spot and forward exchange rates spanning from March 2001 to December 2022. We find that although the spot rate itself present excessive behavior especially after 2014, spot-forward differentials are not explosive, meaning that there is no evidence of rational 'speculative' bubbles in USD/TRY exchange rate over the sample period.

This thesis is organized as follows: Chapter 1 briefly introduces the general terminology and theoretical approaches to bubbles. Chapter 2 provides the relevant literature review. Chapter 3 summarizes the recent performance of Turkish Lira. Chapter 4 outlines the bubble testing methodologies. Chapter 5 describes the dataset and discusses the results from empirical application. The final chapter concludes.

# CHAPTER 1

# DEFINITIONS AND THEORETICAL APPROACHES TO BUBBLE IN ASSET PRICES

There are different definitions of the bubble term. The most commonly known definition is that a bubble is above-normal and self-sustaining increase in prices (Brzezicka, 2021). Besides, some authors note that every rapid increase should not be interpreted as bubble (Case & Shiller, 2003; Coskun & Jadevicius, 2017). The available bubble definitions in the literature take into account the following factors: the temporary character of price changes, expectations of future market prices, and the fact that changes in prices cannot be explained by economic fundamentals, including financial imbalances and the law of supply and demand. The elements utilized to develop a typology of price bubbles and a relevant theoretical framework may differ from the above factors. The elements can be listed as follows: fundamentals that can explain asset prices, market mechanisms, and rational expectations of market participants (Brzezicka, 2021).

The bubble term often mentions a fundamental value because deviation from this value is what indicates the emergence of a bubble. The fundamental value here refers to the expected discounted sum of future price and income when the asset is sold in infinite future (Jarrow et al., 2010). Peter Garber writes in his book Famous First Bubbles: “The definition of bubble most often used in economic research is that part of asset price movement that is unexplainable based on what we call fundamentals” (cited by Garber, 2000, p. 4). According to J. Barley Rosser, professor in the Department of Economics at James Madison University, a more precise understanding of the term “fundamentals” is required in order to define bubble accurately. He writes: “A speculative bubble exists when the price of something does not equal its market fundamentals for some period of time for reasons other than random shocks. Fundamental is usually argued to be a long-run equilibrium consistent with a general equilibrium” (cited by Rosser, 2000, p. 107).

When defining bubbles, the behavior of market participants play a crucial role as they may be rational or irrational. Since we generally assume the market is efficient, and the price of an asset in an efficient market is expected to equal its fundamental value, any divergence is often seen as inefficiency. Bubbles, in this sense, are often associated with irrational behavior because they involve a departure from rational decision-making based on fundamental analysis (Cagli & Evrim, 2018). In an irrational bubble, investors make rash decisions without considering important market fundamentals and purchase the asset at inflated prices (Salge, 1997). On the other hand, as noted by Blanchard and Watson (1982), asset prices may deviate from their fundamental values and show inflated levels without assuming that the market participants are acting irrationally, which brings bubble theory and rational behaviors together (Citak, 2019). Namely, a rational bubble occurs when investors buy an asset at an overvalued price with the belief that it will continue to increase. This behavior of investors shows the rationality of staying in the market despite the overvaluation of the asset (Citak, 2019). Eventually, the expected increase indeed becomes the reality as the value of the currency continues to increase due to demand. This situation can continue for a period of time, yet cannot go on forever. When the deviation becomes too large that a sharp decrease is inevitable. As a result, the currency price returns to its fundamentally determined price. Importantly, the presence of the bubble cannot be ignored by savvy investors who are willing to procure profits. It should be included in the information set which is used by market participants.

The first mention of the rational bubble concept, may be not the term itself, became available in the literature with the paper of Blanchard (1979). He states that the connection between rational expectations and bubbles is possible (DeRosa, 2021). Hence, the main feature that distinguishes a rational bubble from other bubble types is that it can be observed within rational expectations models. Flood and Hodrick define rational expectations as “the requirement that the subjective expectations of the agents in an economic model be identical to the mathematical expectations of the model that are produced by exogenous sources of uncertainty interacting with the behavior of the agents” (Flood & Hodrick, 1990, p. 86). The allure of this connection is that it allows economists to maintain some level of rationality while giving bubble theorists the opportunity to make their point.

## 1.1. RATIONAL BUBBLE THEORY

This study will mainly focus on the largest part of modern bubble research, which is rational bubbles. The rational bubble theory questions the fundamental assumptions of the efficient market theory and plays an important role in search of why asset prices deviate from their fundamental or intrinsic values. A rational bubble reflects self-confirming beliefs about future rises in an asset's price (Kubicová & Komárek, 2011). Investors buy the asset even though they know the value of the asset is not the value set by its economic fundamentals because they believe that they will be able to sell that asset at a later time for a profit (Manap & Omar, 2014). Therefore, asset prices consist of not only a fundamental component but also a bubble component, and rational bubble theory covers these two components (Miao, 2014). The fundamental component presents the discounted sum of the stream of future earnings that an asset will yield over time. The bubble component presents the portion of the assets's price that is not justified by its fundamentals. If the bubble component is equal to zero, then the asset price is solely determined by the fundamental component, and there is no bubble. If the bubble component is greater than zero, it indicates that a bubble is present (Kirman et al., 2007; Maldonado et al., 2012).

To understand the formation of rational bubbles in the simplest way, we consider the following expression for asset prices:

$$x_t = z_t + \alpha.[E(x_{t+1} - x_t)|I_t] \quad (1)$$

Where the variable $x_t$ represents the (logarithm) of the equilibrium asset price at time t; the variable $z_t$ is a scalar representation of the current period fundamental conditions, such as supply and demand, affecting the price of the asset; $[E(x_{t+1} - x_t)|I_t]$ represents the expected percentage change in the asset price from period t to t+1 based on all available information; and $\alpha$ is a positive constant factor that represents the flexibility of the current asset price to market expectations.

Equation 1 suggests that the current period fundamentals and the expected future gain or loss from holding the asset until the next period are the determinants of the spot asset price. The equation also involves the idea of rational expectations. The expectation of the change in the asset price is the mathematical expectation operator using all available information.

Rearranging the above equation yields

$$x_t = \frac{1}{(1+a)}.z_t + \frac{a}{(1+a)}E[x_{t+1}|I_t] \quad (2)$$

This is a stochastic difference equation that is used to model the changes in the asset price over time, taking into account both the fundamental factors, zt, and the presence of random factors that affect the asset price. Furthermore, the law of iterated expectations (LIE) is utilized. This essentially means that the currency value of the expected future value of a random variable, x, is equal to the currency expected value of the same variable x. Formally, it can be expressed as: $E[E[x|I_{t+1}]|I_t] = E[x|I_t]$, where the set of information $I_t$ is contained within the set of information $I_{t+1}$. With the law of iterated expectations, Equation 2 can be solved recursively forward T periods, resulting in the following formula:

$$x_t = \frac{1}{(1+a)}\sum_{i=0}^{T}\left(\frac{a}{1+a}\right)^i E[z_{t+i}|I_t] + \left(\frac{a}{1+a}\right)^{T+1} E[x_{t+T+1}|I_t] \quad (3)$$

One solution to the stochastic difference equation 2 can be expressed as follows:

$$x_t = \frac{1}{(1+a)}\sum_{i=0}^{\infty}\left(\frac{a}{1+a}\right)^i .E[z_{t+i}|I_t] \equiv x_t^* \quad (4)$$

Equation 3 establishes the fundamental or intrinsic value of the asset price at time t, represented as $x_t$*. The term $x_t$ is an exponentially weighted sum of current and expected future values of all relevant economic fundamentals.

However, this form holds when the below condition is satisfied:

$$\lim_{T\to\infty}\left(\frac{a}{1+a}\right)^{T+1} E[x_{t+T+1}|I_t] = 0 \quad (5)$$

If this condition does not hold, the fundamental solution $x_t$ corresponds to only one of an infinite number of solutions of the stochastic difference equation 2.

Each solution takes the general form expressed as:

Observed asset price = fundamental value + rational bubble

Or equivalently,

$$x_t = x_t^* + B_t \quad (6)$$

Where $x_t^*$ is described in Equation 4, and $B_t$ is the rational bubble component of the asset price. It is the difference between the actual price and its intrinsic value based on current economic fundamentals. $B_t$ satisfies the below condition:

$$B_t = \left(\frac{a}{1+a}\right) E[B_{t+1}|I_t] \quad (7)$$

Or

$$E[B_{t+1}|I_t] = \left(\frac{1+a}{a}\right) . B_t \quad (8)$$

This condition requires that the bubble must reflect the expectation that it will continue to grow in the next period for a bubble to be a feasible outcome. If condition 7 holds, then $B_t$ is equal to zero, which means that the observed price is in line with its long-term equilibrium value.

### 1.2. CATEGORIES OF RATIONAL BUBBLE

According to Scherbina and Schlusche (2014), and Wöckl (2019), we can categorize rational bubbles into four groups. The first important differentiation is that investors have symmetrical or asymmetrical information. Furthermore, Froot and Obstfeld (1991) proposed intrinsic bubbles. Finally, we also include agency-based models to explain bubbles in asset prices.

Under symmetric information, rational bubbles may emerge when all investors have rational expectations and possess the same information. In this case, market participants buy an overvalued but only continue to hold if it expands infinitely. Assets with a finite life, at the end of the asset's life, T, will be sold at its fundamental value. Thus, if market participants know that the bubble explodes at T, no one would pay more than the fundamental price at T-1, which causes the bubble to burst at T-1. Similarly, a bubble would not occur at T-2, T-3, and so forth. Consequently, bubbles can only exist in assets that have an infinite lifetime (Brunnermeier, 2008; Barberis et al. 2018; dos Santos, 2020).

Rational bubbles may also emerge under asymmetric information. Asymmetric information refers to a situation where some investors have knowledge that there is a bubble in the asset, and others do not. More precisely, there is no common knowledge that the market is experiencing a bubble. Due to uneven distribution of knowledge, finite bubbles can be present under certain conditions. Kindleberger and Aliber (2015) refer to this type of rational bubbles as greater fool theory because economic agents hold the overvalued asset with the expectation of reselling it at a higher price to another agent who drive up the price based on the particular information that they know. The theory suggests that a bubble is formed by the presence of greater fools, and it ends when there are no greater fools left in the market.

Froot and Obstfeld (1991) introduce the concept of intrinsic bubbles, which is a different type of rational bubbles. Intrinsic bubbles differ from other types of bubbles as they consider the bubble component of an asset’s price to be a deterministic function of the fundamental factors rather than a function of time. This type of bubbles has several advantages. First, if fundamentals remain constant over time, the bubble also stays at the same level; however, if market fundamentals change, asset prices overreact to those changes. Second, the bubble does not have to burst in relation to the fundamental value, and the final advantage is that the bubble may even vanish completely.

Lastly, agency-based models are another group of economic models that explain the emergence of asset price bubbles as a result of the actions of market participants. These models typically focus on the behavior of agents, such as investors or traders, and how their actions and decisions can lead to the creation and growth of bubbles in asset prices. These models usually take into account factors such as herd behavior, information asymmetry, and incentives for agents to deviate from rational expectations.

### 1.3. IRRATIONAL BUBBLE THEORY

Alternative explanations exist for bubbles that do not rely on the presupposition of complete rationality among investors, such as models that consider irrational bubbles (also known as behavioral bubble models). Irrational bubbles incorporate the idea that market participants, in addition to making decisions based on rational analysis, can also be influenced by psychological biases such as herding behavior, overconfidence, and the tendency to extrapolate past trends. These models can help explain why asset prices deviate from their fundamental values, and potentially form "bubbles" where prices become detached from reality (Wöckl, 2019).

### 1.4. CATEGORIES OF IRRATIONAL BUBBLE

Four categories account for irrational decisions: disagreement-based models, feedback trading, biased self-attribution, and representativeness heuristic and conservatism bias (Scherbina & Schlusche, 2014; Wöckl, 2019).

Irrational bubbles can emerge as a result of disagreement-based models. These models assume that investors have heterogeneous beliefs on asset valuations. Opinions play an important role in forming valuations. Different opinions can cause the deviation of prices from fundamental values and market inefficiencies, such as bubbles and crashes (Wöckl, 2019). Therefore, these models can be used to predict and explain market events, such as the formation of bubbles and the persistence of mispricings.

The irrational behavioral can also be explained by feedback trading. In these models, an asset reacts to good news and experiences an initial price increase. If a group of traders, referred to as feedback traders, notice this price increase, they buy the asset, and their purchasing decision relies on past price movements rather than the asset’s present value. Eventually, the price increases attract more feedback traders, and the price continues to increase. While trader’s demand for the asset pushes prices even higher, this behavior amplifies mispricings and leads to prices that exceed the fundamentals (Wöckl, 2019).

Another category of irrational bubble models is biased self-attribution. This category suggests that individuals have a psychological tendency to prioritize information that validates their personal expectations and beliefs while disregarding other relevant information that contradicts their predictions (Daniel et al., 1998). The first investigation of bubble phenomena with biased self-attribution was conducted by Daniel et al. (1998). Their model suggests that the bubble bursts when the positive beliefs that led to the price exubarence are reversed (Wöckl, 2019).

The last category of irrational bubbles is a combination of the representativeness heuristic and the conservatism bias. These models explain the formation of bubble by showing how cognitive biases influence the probability of events under uncertanity. The representativeness heuristic occurs when individuals determine the probability of an uncertain event based on how similar it is to a known situation, rather than using statistical information. The problem with this is errors may occur in judgment and decision making as individuals may overestimate or underestimate the probability of a certain event. When applied in finance, the representativeness heuristic implies that investors may use the past performance of an asset as a guide to its future performance, rather than considering more objective information such as the fundamentals of the asset or the overall market conditions. This can lead to investors overvaluing an asset, as they assume that its past performance is representative of its future performance, which can contribute to the formation of a bubble (Wöckl, 2019). Additionally, investors may also ignore warning signs of a bubble because it does not match with their preconceived notion of how a bubble should behave. This further reinforces their belief in the bubble and leads to a continuation of the bubble. As for conservatism bias, it refers to tendency for people to prefer pre-existing information over new information that may change their beliefs and predictions. This bias can lead individuals to make conservative (i.e., less extreme or less risky) predictions or decisions, rather than updating their beliefs in light of new evidence. In the financial context, that implies investors underestimate the extent of the price increase and underreact to the presence of a bubble.

## 1.5. RATIONAL BUBBLES IN FX MARKET

Since the methodology of Pavlidis et al. (2017) is applied to our analysis, this section largely borrows from their paper. Taking into account rational expectations models, the log exchange rate $s_t$ is formulated with a rational bubble term $B_t$ and economic fundamentals $x_t$. Rational expectations models assume that market participants have rational expectations about future exchange rates, based on their analysis of economic fundamentals and past experience. As a result, market participants are assumed to adjust their expectations and behavior in response to new information. In the context of bubbles, if they expect that the value of a currency will continue to increase, this expectation becomes self-fulfilling. This is formulated as follows:

$$s_{t=}\ x_t + B_t \qquad (9)$$

Where $s_t$ denotes (the logarithm of) the exchange rate, $x_t$ denotes economic fundamentals affecting the exchange rate, and $B_t$ denotes a rational bubble term. Numerous exchange rate models follow this general structure (Engel et al., 2007). The basic monetary exchange rate model is the most popular of these models where the fundamental value of the exchange rate, $x_t$, denotes the discounted sum of current and expected future relative money supplies and relative incomes (Mark, 1995).

Pavlidis et al. (2017) simplify the analysis by assuming that the fundamental component, $x_{t,}$ follows a first-order autoregressive process AR(1). The AR(1) model is a linear function of the value of x at time t-1 on the value of x at time t as illustrated below:

$$x_t = \emptyset \mathrm{x}_{t-1} + u_t \tag{10}$$

where $u_t \sim$ iid(0, $\sigma_u^2$ ), meaning that $u_t$ is a white noise process with a normal distribution that has zero mean and constant variance $\sigma_u^2$ (Pavlidis et al., 2018).

The rational bubble term $B_t$, which is the second element of the spot price, satisfies the rational expectations requirement postulated by Diba and Grossman (1988).

$$E_t B_{t+1} = (1 + r) B_t \tag{11}$$

where $E_t$ is used to describe the expectations of economic agents at time t, and (1+r) denotes the expected growth rate of the bubble where the parameter r is a positive constant obtained from the model describing the exchange rate.

Furthermore, Pavlidis et al. (2017) follow the most popular rational bubble process proposed by Blanchard (1979). This bubble process is influenced by non-fundamental factors, and it has two states. In the first state, the bubble survives with probability $\pi$ and continues to grow at an expected rate (1+r)/$\pi$ until the next period. In the second state, there is a probability of (1 – $\pi$) that the bubble collapses in the present period. In case of bubble collapse, the price of the asset returns to its fundamental value.

$$B_{t+1} = \begin{cases} \frac{(1+r)}{\pi} B_t + \epsilon_{t+1} & with\ prob. (\pi) \\ \epsilon_{t+1} & with\ prob. (1 - \pi) \end{cases} \tag{12}$$

and consequently, 12 satisfies 11.

## 1.6. DETECTING RATIONAL BUBBLES IN PRACTICE

In the literature, various approaches have been proposed to detect and analyze rational bubbles. This section discusses different detection techniques employed in practice and their respective advantages and limitations.

### 1.6.1. Detection Techniques with Model Specification for Fundamentals

In the case of the first state described in Equation 12, the bubble term exhibits an explosive AR(1) process. Similarly, Equation 9 reveals that the spot rate also displays explosive dynamics. On this basis, it is common in the literature to test for bubbles by running unit root tests on prices as mentioned in Section 2.2. However, despite their widespread usage,  unit root tests can lead to false inferences. This is because asset prices can display explosiveness even in the absence of bubbles as long as other component, namely fundamentals, exhibits explosive dynamics (i.e., $\varphi > 1$). Since unit root tests fail to account for explosive fundamentals, the results may not offer conclusive evidence.

Researchers have applied various techniques to tackle this “fundamental” problem, and they include fundamental factors in their analysis. One of the techniques is conducting unit root tests on ratios that compare asset prices to fundamentals, such as stock prices to dividends and house prices to income. Furthermore, they also check whether there is cointegration between asset prices and fundamentals. Additionally, they compare the level of the variability in asset prices with that expected from fundamentals. A common problem of all these techniques is that they do not lead to a clear and final result. In the context of testing for bubbles, it is crucial to consider all relevant factors and avoid errors in measurement. Any crucial variable unknown to researchers may generate a biased result that could potentially lead to the rejection of the idea of a bubble. This is known as the joint-hypothesis problem, where the rejection of the null hypothesis may be due to the misspecification of fundamental factors, the presence of speculative bubbles, or a combination of both (Hamilton & Whiteman 1985, Gurkaynak 2008).

### 1.6.2. Detection Technique without Model Specification for Fundamentals

As models for fundamentals are uncertain, Pavlidis et al. (2019) focus on derivative markets that might provide useful information in this context. This section largely borrows from Pavlidis et al. (2017). Under risk neutrality, (the logarithm of) the forward rate at time t with maturity n-periods ahead, $f_{t,n}$, is equal to

$$f_{t,n} = E_t(s_{t+n}) = E_t(x_{t+n}) + E_t(B_{t+n}) \quad (13)$$

The above expression can be re-expressed by using Equations 10 and 11

$$f_{t,n} = \emptyset^n x_t + (1+r)^n B_t \quad (14)$$

Re-arrenging Equation 9 with n periods gives us the future spot rate formula at t + n

$$s_{t+n} = x_{t+n} + B_{t+n} \quad (15)$$

If a bubble persists, the actual spot rate at t+n is specified as follows

$$s_{t+n} = \emptyset^n x_t + \left(\frac{1+r}{\pi}\right)^n B_t + \epsilon^*_{t+n} \quad (16)$$

Where $\epsilon^*_{t+n}$ has two moving average processes, $\sum_{i=1}^{n} \emptyset^{n-i} u_{t+i}$ and $\sum_{i=1}^{n} \left(\frac{1+r}{\pi}\right)^{n-i} \epsilon_{t+i}$. By comparing Equation 14 and 16, we can observe that the expected future spot rate is higher than the forward rate. Therefore, substracting equation 14 from equation 16 yields

$$s_{t+n} - f_{t,n} = \left(\emptyset^n x_t + \frac{(1+r)^n}{\pi^n} B_t + \epsilon^*_{t+n}\right) - (\emptyset^n x_t + (1+r)^n B_t) = (1+r)^n \left(\frac{1}{\pi^n} - 1\right) B_t + \epsilon^*_{t+n} \quad (17)$$

The above equation displays the divergence between the actual future spot rate and the forward rate. The reason for this divergence can be attributed to the uncertainty of rational agents at time t regarding the persistence of the bubble and thus assign a nonzero probability to its collapse when forming expectations. Accordingly, their expected growth rate $(1+r)^n$ of the bubble component falls short of the actual rate of $(1+r)^n / \pi^n$.

As stated in the paper of Pavlidis et al. (2017), researchers can simply run unit root tests on $s_{t+n} - f_{t,n}$ to test for bubbles. Given that the equation involves two moving average processes, it contains explosive dynamics. Contrary to tests on the spot rates ($s_t$) of not depending on fundamentals, running unit root tests on $s_{t+n} - f_{t,n}$ can offer conclusive evidence that supports the presence of speculative dynamics. Like Pavlidis et al. (2017), this study utilizes the time series characteristics of the difference between future spot rates and market expectaions represented by forwad rates. In this approach, it is not necessary to have a clear and specific definition of economic fundamentals.

# CHAPTER 2

# REVIEW OF EMPIRICAL LITERATURE ON BUBBLE DETECTION

This chapter reviews the literature on bubble detection with the focus on empirical strategies employed and findings about the presence of rational bubbles in major currency pairs.

## 2.1. LITERATURE REVIEW ON ECONOMETRIC TECHNIQUES FOR BUBBLE DETECTION

There are several bubble detection techniques that mainly depend on fundamentals specification except for the technique developed by Pavlidis et al. (2017). Early research related to bubble detection methods dates back to the 1980s. Flood and Garber (1980) were the first to empirically test the occurrence of bubbles in the context of German Hyperinflation. They define the bubble as what remains after removing market fundamentals from the price (Flood & Hodrick, 1986). The other methods include variance bounds tests (also called volatility tests) of Shiller (1981) and Leroy and Porter (1981), the unit root (stationary) tests proposed by Diba and Grossman (1984), and cointegration-based tests advanced by Campbell and Shiller (1987, 1988), and Diba and Grossman (1988) as cited in Otero et al. (2021).

### 2.1.1. Variance Bounce Tests

Variance bounds tests compare the actual price volatility with the fundamental price volatility. If the assumed fundamental price is not as volatile as the actual price, one can infer that there is something other than fundamentals (de Oliveira & Almeida, 2014). Although Shiller (1981), and Leroy and Porter (1981) observe excessive volatility in their empirical study, they do not mention bubbles as a potential explanation. However, the excessive volatility is seen as evidence of bubble in later applications (Brunnermeier, 2008). Blanchard and Watson (1982) are the first authors to suggest applying these tests for identifying bubbles empirically (Arshanapalli & Nelson, 2016). They analyze the real prices and real dividends of the S&P 500 index. They find that the variance bound is violated, which they interpret as a possible indication of the presence of a bubble.

However, they also state that this violation could stem from other factors besides bubbles, such as irrationality. Tirole (1985) also states that the presence of bubbles could be the cause of the violation, which means that bubbles are responsible for price fluctuations in assets.

Variance bounds tests are mainly model-dependent tests of bubbles. This is a serious obstacle as it requires to be jointly tested whether there is a bubble in the data and the model provides accurate prediction for the asset's value (Arshanapalli & Nelson, 2016). When testing bubbles with variance bounds tests, the null hypothesis assumes that there is no bubble present in the price of an asset. However, rejecting of the null hypothesis does not necessarily mean that a bubble exists as other factors may also contribute to the rejection. Alternative explanations can be model misspecifications or presence of more than one bubble. In the literature, this issue is called the joint hypothesis problem and the economic fundamentals should be correctly identified to avoid it (DeRosa, 2021).

Since variance bounds test has serious problems, Campbell and Shiller (1987) and Diba and Grossman (1988) propose another class of econometric models for testing bubbles, cointegration tests, and unit root tests, respectively. These models examine the relationship between asset prices and its fundamentals by focusing on the left side of the probability distribution of the test statistic. Thus, their test imposes a structure where deviations from fundamental value in the series are responsible for the occurrence of bubbles (Gurkaynak, 2008).

### 2.1.2. Cointegration Tests

Cointegration tests examine the long-run relationship between two variables. If two variables are found to be cointegrated, this indicates a high correlation between these two series or an equilibrium between them (de Oliveira & Almeida, 2014). Thus, if the movement of one variable affects the other, one can conclude that there is no bubble in the series (de Oliveira & Almeida, 2014). Campbell and Shiller (1987) construct cointegration tests to empirically explain the bubble presence and apply these formulations to the S&P 500 stock price index, using annual data from 1871 to 1986 and to the series of US Treasury 20-year yield, using monthly data from 1959 to 1983. They conclude that a bubble exists in both series.

Another paper from Froot and Obstfeld (1991) tests intrinsic bubbles in the S&P 500 stock price index by employing cointegration tests, using annual data from 1900 to 1988. As mentioned in Chapter 1.2., intrinsic bubbles are solely influenced by fundamentals, and follow a nonlinear pattern, thereby requiring a nonlinear relation between stock prices and dividends (Ma & Kanas, 2004). Similar to the paper of Campbell and Shiller (1987), the findings of Froot and Obstfeld (1991) reveal evidence for a non-linear relationship between stock prices and dividends. They note that this nonlinearity can be interpreted as a sign of bubbles when the model is indeed linear as they assume. Furthermore, they acknowledge that alternative explanations may be valid if the true model is actually nonlinear (Gurkaynak, 2008).

### 2.1.3. Stationarity Tests

Diba and Grossman (1988) suggest investigating the stability of the link between asset prices and fundamentals as well as the stationarity properties of these variables. The reason behind their approach is that if stock prices display more significant growth than dividends over time, it may indicate a bubble. To determine the presence of a bubble, the authors utilize unit root tests. They apply these tests to the S&P stock price index and search the empirical evidence of explosive rational bubbles using annual data ranging from 1871 to 1986. The findings show that the data is non-stationary in levels, but stationary in differences. Since the authors test the null hypothesis of no bubbles and fail to reject it, they conclude that there are no explosive rational bubbles in the stock prices. Diba and Grossman (1988) conduct further tests that support the presence of cointegration between stock prices and dividends over the same period. This means that prices do not significantly deviate from the long-run fundamentals, and as a result, explosive rational bubbles do no exist in the data (Otero et al., 2021).

### 2.1.4. Right-Tailed Unit Root Tests (Periodically Collapsing Bubble Tests)

Considering that all above tests have different characteristics in terms of power/size and provide different results, Evans (1991) criticizes the reliability of the mentioned methods. He shows through simulation methods that they have low power in detecting complex patterns such as bubbles. The underlying reason for the failure of these tests is that bubbles are prone to periodical collapses, and this property of bubbles may actually make the series look like a stationary (nonexplosive) process and cointegrated with market fundamentals (Pavlidis et al., 2017).

In an attempt to eliminate the problem of detecting periodically collapsing bubbles, a recent advancement promises a recursive procedure. Given the limited ability of standard unit root tests to distinguish a periodically collapsing bubble process from a pure unit root process, recursive unit root tests offer a big advantage as they examine each subsample on a period basis. This modification is pioneered by Phillips et al. (2011), and later refined by Phillips et al. (2015a). The authors propose the Supremum Augmented Dickey-Fuller (SADF) and Generalized Supremum Augmented Dickey-Fuller (GSADF) tests respectively, which have become one of the most commonly used tests for bubbles. Similar to standard unit root tests, recursive unit root tests rely on the assumption that prices follow a random walk. In other words, prices generally exhibit a unit root, with the exception of periods where they demonstrate significant deviation from their fundamental values. That deviation may be due to explosive behavior or a bubble. This is precisely the phenomenon that is being investigated by using recursive unit root tests. (Bohl et al., 2013).

Philips et al. (2011) introduced the supremum ADF test as an extension of the unit root testing methodology originally proposed by Diba and Grossman (1984). The SADF test, which is based on the ADF model, repeatedly estimates the model on a forward-expanding sample sequence (El Montasser et al., 2016). Put simply, the purpose of this approach is to account for explosive behavior in time series by sequentially testing sub-periods of the series (windows). Moreover, simulations conducted by Homm and Breitung (2012) demonstrate that the SADF test works well in detecting structural breaks and is more powerful than alternative bubble tests. However, the SADF test is not reliable when there are multiple bubbles in the sample. Phillips et al. (2015a, 2015b) also highlight this issue of the SADF test and propose an alternative test called the generalized sup ADF test. This test is the largest ADF statistic. The GSADF test performs recursive right-tailed unit root tests as in the SADF test. However, while the SADF test fixes the starting point in the recursive regressions, the GSADF test uses a more flexible window size than the SADF test since it changes the starting and ending point of the sample. This flexibility allows the GSADF test to detect multiple periods of exuberance (explosive behavior) and collapse.

## 2.2. EMPIRICAL LITERATURE ON DETECTING BUBBLES IN FX MARKETS

The identification of bubbles across various markets, such as stock, housing market, and foreign exchange, has been the subject of numerous studies in the literature. For the purposes of this thesis, we focus on reviewing empirical literature testing bubbles in FX markets. The list includes different currency pairs (Wu, 1995; Jirasakuldech et al., 2006; Bettendorf & Chen, 2013; Jiang et al., 2015; El-Montasser et al., 2016; Hu & Oxley, 2017; Pavlidis et al., 2017; Ural, 2021). The case of Turkish Lira has also been the topic in the papers by Korkmaz et al. (2016), Afsar et al. (2019), Gulcan et al. (2021), Gok (2021), Isildak (2022), Sarikamis (2022), Yildirim et al. (2022), and Karcioglu and Ozcan (2023).

In the Wu (1995) study, price bubbles in US dollar - British pound, US dollar - Japanese yen, and US dollar - Deutsche mark exchange rates are examined by applying the Kalman filter. His aim is to test the post-Bretton Woods period, and he uses monthly data between the years 1974 – 1988. As a result of the analysis, he finds no significant presence of a bubble component.

Another notable paper is conducted by Jirasakuldech et al. (2006). They examine the presence of rational speculative bubbles in exchange rates between the US Dollar and five currencies (the British pound, the Canadian dollar, the Danish krone, the Japanese yen, and the South African rand) at a monthly frequency during the sample period 1989-2004. They use the end of month spot exchange rates for each currency and apply the following fundamental factors: short-term interest rate, money supply, CPI, and industrial production. Three tests (unit root, cointegration, and duration dependence tests) are employed. Firstly, they check the stationary analysis of the exchange rate series and each fundamental variable by the augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit root tests. The results reveal that none of these variables exhibit stationary behavior, whereas all variables are stationary in the first difference. Second, they aim to see if a long-run relationship exists between the exchange rate and the underlying fundamental variables. For that reason, they perform the Johansen's multivariate cointegration tests by using the monetary approach. The results demonstrate strong cointegration between the spot exchange rates of each currency and fundamental variables. Finally, duration dependence test is applied. This test does not require the identification of fundamental factors that determine the exchange rates. Thus, it eliminates the issue of the joint null hypothesis of no bubble and model misspecification. The result shows that no bubbles exist.

Bettendorf and Chen (2013) examine the behavior of Sterling-dollar exchange rates by using unit root tests (ADF, SADF, and GSADF) for a period of forty years, from 1972 to 2012, on a monthly basis. The authors find strong evidence of explosive behavior in the time series. To better understand the causes of this explosiveness, they further examine whether there is explosive behavior in the underlying fundamentals. They use the relative prices of traded and nontraded goods as fundamentals constructing from the producer price index (PPI), the consumer price index (CPI), and retailer price index (RPI). It is concluded that the actual reason behind the explosiveness is explosive behavior in the relative prices of traded goods. Finally, they emphasize the importance of the underlying fundamentals in search of bubbles.

Since China became the second-largest economy in 2010, China's exchange rate has also been a hot topic (Jiang et al., 2015). The presence of bubbles in the USD - RMB was investigated by Jiang et al. (2015) and El-Montasser et al. (2016). Jiang et al. (2015) apply the recently developed GSADF test to the Chinese RMB-US dollar exchange rates. The sample period used for the study ranges from July 1995 to October 2013. According to the results obtained by the authors, there is strong evidence of bubbles including two periods. The first bubble occurs during 2005-2006 after the 2005 exchange rate regime reform, and the second bubble occurs in 2008 when subprime crisis happened. They indicate that the first bubble cannot be attributed to the relative prices of either traded or non-traded goods, whereas the second bubble can only be attributed to the relative prices of traded goods. Similarly, El-Montasser et al. (2016) show that bubbles are present in the Chinese RMB-US dollar exchange rate from 2015 onwards, and they attribute the explosive behavior of the exchange rate to the differences in the relative price of traded goods.

Numerous studies have applied recursive unit root tests to examine large fluctuations in exchange rate series. In addition, the work of Pavlidis et al. (2017) has offered a different perspective to bubble research. They utilize the difference between the forward exchange rate and the future spot rate. The advantage of this method is that there is no need to specify a model for fundamentals. It looks at the differences between forward and spot prices. The underlying idea is quite straightforward: When a bubble forms in the market, it causes the forward exchange rate and the future spot rate to differ and the gap between the two rates displays explosive dynamics. As long as the same explosive dynamics do not coincide with the forecast errors for fundamentals, the existence of explosive dynamics in the divergence between the two rates can be associated to the presence of bubbles. Their framework differs from previous works in one important way. They basically combine the unbiased forward rate hypothesis with the bubble search. In the study, Pavlidis et al. (2017) investigate the presence of bubbles in exchange rates and equities with Fama regression and GSADF analysis. They point out the power of the GSADF test in their method for the purpose of detecting bubbles by using Monte Carlo Simulations. Their data set involves the German mark-US dollar exchange rates and the British pound-US dollar exchange rates. While the results provide evidence of bubbles in the Mark-US dollar during the German hyperinflation period, no bubbles are found in the British pound-US dollar exchange rates. Additionally, they analyze the S&P 500 index to demonstrate the effectiveness of their methods in other markets. Similar to the exchange rate market, the presence of bubbles in this market is observed.

Hu and Oxley (2017) aim to detect the presence of exchange rate bubbles in some G10, Asian and BRICS countries. They apply the GSADF test of Phillips et al. (2015a) to the monthly data from March 1991 to December 2014. In general, the authors conclude that most exchange rate pairs do not show evidence of bubbles with few exceptions. Specifically, they observe bubbles in the Sterling-Swiss Franc and Sterling-Japanese Yen cross rates among the G10 currencies. Asian currencies also have bubbles during the 1997 Asian Financial Crisis. However, no evidence of bubbles was found in three BRICS countries, namely Brazil, India, and South Africa, instead, the majority of movements are associated with the relative prices of traded goods. Last, they observe strong explosiveness in the US Dollar-Colombian Peso exchange rate and the US dollar-Mexican Peso exchange rate. However, while the explosiveness in the US dollar-Colombian Peso is explained by the relative prices of traded goods, a bubble is found in the US Dollar-Mexican Peso during the Mexican peso crisis 1994-95.

Elike and Anoruo (2017) investigate the presence of explosive bubbles in the South African rand – US dollar exchange rate for the period 1980 to 2012 at a monthly frequency. The authors employ three tests (the ADF, the SADF, and the GSADF) to examine the logarithm of the nominal exchange rate as well as the logarithms of the ratios of the relative prices of nontraded and traded goods. They consider the ratios of the relative prices of nontraded and traded goods as fundamentals for exchange rates. According to their findings, the ADF test reveals that there is explosiveness in the rand-dollar exchange rate, however the ADF test is not accurate when periodically collapsing bubbles exist in the data. For that reason, they also look at the results from the SADF and GSADF tests. It appears that there are bubbles in the nominal exchana geta, relative prices of traded goods, and the relative prices of nontraded goods. They find three bubble periods and conclude that these explosive behaviors in the exchange rate are caused by movements in both the relative of traded and nontraded goods.

Ural (2021) employs the GSADF test to analyze the nominal USD/KZT exchange rates, using weekly data for the period August 2015 to April 2021. The empirical findings display two explosive bubbles in 2018 and 2020. The author emphasizes that the bubble periods coincide with the periods when the US applies sanctions on turkey and Russia, the interest rates increase in Turkey and Russia, the oil price war between Russia and Saudi Arabia and the oil's historic plunge with the onset of the COVID-19 outbreak . He indicates that bubbles may form due to foreign or domestic economic events, thus the listed events might have triggered the occurrence of the bubble in USD/KZT.

After starting a floating exchange rate regime in 2001, Turkish FX market has experienced frequent and erratic changes in prices. In order to investigate these changes, several papers highlight the applications to Turkish lira exchange rate series and provide empirical contribution to the studies on currency bubbles. We briefly look at those studies below.

Korkmaz et al. (2016) investigate the effects of bubbles occurring in USD/TRY and EUR/TRY on volatility of BIST 100. For this purpose, they examined if nominal exchange rates are explosive using SADF and GSADF tests. The study utilizes monthly data set for the period of 2002-2016. Their findings point out the existence of bubbles in the USD/TRY rate, but no bubble was found for the EUR/TRY rate.

Korkmaz (2018) investigates the presence of bubbles in the euro, the dollar, gold, and bitcoin variables to understand whether the detected bubbles have any impact on bitcoin. To conduct this assessment, Korkmaz (2018) utilizes the SADF and GSADF tests. The analysis covers the period from August 1, 2018, to March 23, 2018, using daily data. The study confirms the presence of bubbles in the euro and dollar. Notably, the dollar exhibits a continuous bubble state starting from August 2013 until mid-February 2017.

Afsar et al. (2019) analyze the existence of bubbles in USD/TRY and EUR/TRY exchange rates. The data set is taken from January 2005 to November 2018. In the study, they apply the GSADF test, and find evidence of bubbles for both USD/TRY and EUR/TRY. According to the findings, there are five bubble episodes in dollar exchange rate prices; the first bubble emerged in the last quarter of 2008, the other ones were seen in early 2014, the last quarter of 2015, from the last quarter of 2016 to mid-2017, and the last one appeared from May 2018 to the last quarter of 2018. Similarly, the authors present evidence of five bubbles for EUR/TRY; a bubble has formed in the ma exchange rate between the May-October period of 2011, mid-2012, the third quarter of 2013 and the beginning of 2014, and the period from the end of 2017 to the fourth quarter of 2018.

Gulcan et al. (2021) test for the existence of bubbles in the most traded currencies in Turkey. The list includes the US Dollar, Euro, British Pound, Japanese Yen, and Chinese Yuan. Daily price data from 28 August 2013 to 20 November 2019 for Japanese Yene are used, while daily price data from 3 January 2010 to 20 November 2019 for the rest are used to conduct the empirical analysis based on GSADF unit root test proposed by Phillips et al. (2013). The GSADF results confirm the presence of bubbles in the foreign exchange market in Turkey. The authors indicate that the Turkish lira has a very fragile structure, and the local and global events easily influence the currency market. Moreover, the USD/TRY and EUR/TRY exchange rates are found to be more sensitive than the other exchange rates.

Gok (2021) examines explosiveness in the Turkish asset prices through the GSADF test using weekly averages ranging between April 2005 to June 2021. The study uses closing prices of two stock indices, namely XU100 and XBANK, denominated in both TRY and USD, as well as data on 2-year bond, gold prices, CDS, and USD/TRY exchange rates. His research confirms two long and six short bubble periods in the exchange rate data. The first formation of a bubble period occurs in 2006. According to his interpretation, it corresponds to exchange rate shock relative to interest rate rise which is indeed one of the main exchange rate fundamentals. Another bubble periods form in 2011 and 2013. In 2013, one driver of the bubble formation in the currency is Gezi Park protests. After 2014, there are a bunch of periods that displays multiple exuberances mainly associated to political uncertainty, interest rate regulations, terrorist attacks, and the general election in Turkey. Another bubble formation in the USD/TRY exchange rate was found between 2016 and 2021. He states that this period is the longest-lived formation lasting about five years. First, it is indicated that the USD value strengthen due to the surprise victory of Trump's US presidential election. Second reason is the political tensions between Turkey and the EU because of the freeze on Turkey's ongoing process for EU membership. Furthermore, heightening prices with the 2018 currency crisis, Trump's economic sanctions, presidential election and the renewal of local elections led to a longer bubble period. The author also highlights that the bubble continues to inflate in 2020 due to the pandemic era and again some fundamental problems (e.g., rising inflation, dollarization rate).

Isildak (2022) examines the presence of speculative bubbles in the US dollar exchange rates, gold prices, and the Istanbul Stock Exchange (BIST) All Shares Index. The study uses the GSADF test and covers the period from July 2018 to July 2022 on a weekly basis. The results of the analysis indicate that there is evidence of the presence of bubbles in all three markets. The US dollar exchange rate, in particular, has five bubble periods, but only four of them are speculative. The formation of the fifth bubble period is attributed to the currency crisis that happened in 2021.

Sarikamis (2022) investigates the formation of bubbles in the exchange rates of the US dollar and Euro from January 2015 to December 2020. The study uses the SADF and GASDF tests. The SADF test results show four bubble formations in the US dollar exchange rate and five bubble formations in the Euro exchange rate. On the other hand, the GSADF test results show five bubble formations in the US dollar exchange rate and four bubble formations in the Euro exchange rate. The study finds that there are several bubble formations in the exchange rates of the US dollar and Euro, with international policies and the impact of US elections on geopolitical risks in Turkey being some of the factors associated with these formations. The author emphasizes the impact of international policies on the formation of bubbles in financial markets.

Ozdemir (2022) examines the presence of bubbles in five exchange rates, namely, the US Dollar (USD/TRY), the British pound (GBP/TRY), the Euro (EUR/TRY), the Chinese Yuan (CNY/TRY) and the Russian Ruble (RUB/TRY) from January 2, 2015, to February 12, 2021. The time period is divided into three categories: pre-COVID-19 (January 2, 2019, to November 15, 2019), COVID-19 (November 18, 2019, to February 12, 2021), and the full-sample period (January 2, 2015, to February 12, 2021). Using daily sampled data (excluding weekends), the study employs the SADF and GSADF test statistics to identify bubble-like behavior in selected exchange rates. The findings reveal evidence of explosiveness across all examined periods for the selected exchange rates, with the exception of RUB/TRY in the SADF test during the COVID-19 period. The author interprets this explosiveness as evidence of bubble activity.

Yildirim et al. (2022) search for bubbles in exchange rates of the BRICS nations (Brazil, Russia, India, China, and South Africa), and the Republic of Turkey. They apply the GSADF test to the US dollar exchange rate data for the sample period extending from 2002 to 2019 at a monthly frequency. Their findings show that price bubbles exist in the dollar exchange rate data of countries other than the USD/INR exchange rate. They highlight the importance of speculative movements in the exchange rates on national economies.

Karcioglu and Ozcan (2023) conduct a study on how asset price bubbles affect the volatility of the BIST 100 index. The study analyzes the presence of bubbles in the dollar, euro, bitcoin, CDS, and deposit interest rate variables using monthly data from August 2010 to October 2022. The SADF and the GSADF tests are applied to detect bubble formations in the variables. The results show that there are bubble formations in the USD, EUR, and BITCOIN variables.

# CHAPTER 3

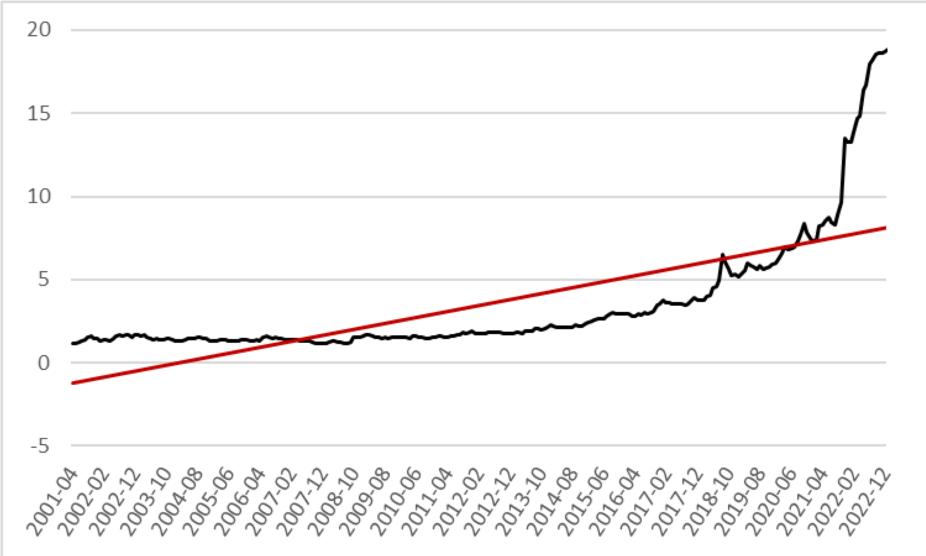
# A BRIEF OVERVIEW OF RECENT PERFORMANCE OF TURKISH LIRA

As the aim of this thesis is to examine the occurrence of rational bubbles in USD/TRY exchange rate, it is worth presenting an overview of exchange rate regimes adopted in Turkey and the performance of Turkish Lira over recent decades.

Turkey has applied different exchange rate regimes over time. Since the exchange rate policies adopted by a country are influenced by its exchange rate regime, it is also important to look over the choice of the exchange rate regime of countries (Aytac, 2016). Until 1980, Turkey followed a fixed exchange rate regime. After then, due to the changing global economic conditions, the authorities decided to switch to a managed floating exchange rate regime, where exchange rates are determined in the market but also influenced by the interventions of CBRT. However, the managed floating exchange rate caused increased volatility and uncertainty in the foreign exchange market. Additionally, the managed exchange rate regime required a significant amount of foreign reserves to support the exchange rate. In 2000, Turkey's decision was to allow the exchange rates to fluctuate within a set band in an attempt to modernize the exchange rate system and improve economic stability, thus the crawling bands regime was adopted. However, the system proved inadequate in the face of the crisis. The crisis that hit to the Turkish economy in 2001 resulted in a massive loss of international reserves (Tumturk, 2019). Due to the crisis, the monetary authorities switched to the floating exchange rate regime. This regime allows exchange rates to fluctuate freely in the market, and exchange rates are no longer driven by CBRT (Kasman & Ayhan, 2006). Exchange rates have moved in a wide range since the adoption of the floating exchange rate regime, and the performance of the Turkish lira has been quite volatile (Kasman & Ayhan, 2006).

The performance of the Turkish lira against the US dollar since 2001 has been subject to significant fluctuations. There have been periods of appreciation and depreciation, influenced by various economic and market factors. The below figure displays the trend of the Turkish lira against the US dollar. However, the Turkish lira has experienced significant depreciation against the US dollar in recent years. For that reason, to provide a clearer illustration, we further divided the period into three groups: 2001-2007, 2008-2017, and 2018-2022.

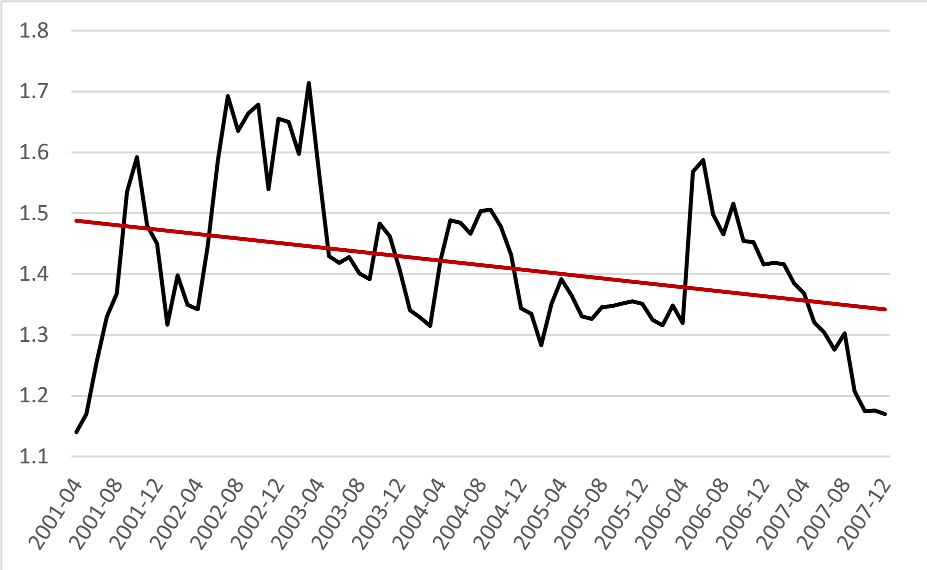
**Figure 1.** The USD/TRY exchange rate data from March 2001 to December 2022




The deterioration in economic balances that began in the 1990s significantly affected the exchange rate market (Temiz & Gokmen, 2009). The worsening economic fundamentals eventually led to a severe currency crisis in 1994, which was further exacerbated by heavy interventions by the central bank in the foreign exchange market. These interventions caused a significant loss of international reserves (Ozatay, 2000). As a consequence, the Turkish lira experienced a significant devaluation against the dollar. The economic challenges continued as Turkey's important trading partner, Russia, faced a crisis in 1998. This further affected the confidence of foreign investors in Turkey. In 1999, Turkey was hit by a devastating earthquake crushing the industrial heartland and deteriorating the country’s economic performance (Ari & Cergibozan, 2016). It necessitated significant efforts and resources to recover and rebuild, impacting various sectors of the economy and contributing to economic challenges in the years that followed. Additionally, in 1999, the Turkish government introduced an exchange rate-based stabilization program supported by an IMF stand-by agreement. The stabilization program aimed at curbing the high levels of inflation. The main element of the program was a pre-announced crawling peg exchange rate regime where exchange rates are daily adjusted (Ozatay & Sak, 2002). After all, while entering the year 2000, the effects of the previous events were still active. Despite the program's efforts, the crisis could not be avoided, and another crisis broke out in December 2000 due to a liquidity problem in the market. The concerns about worsening conditions caused the withdrawal of foreign investors from the market, and a large amount of funds was outflowed. With the support of the IMF, a financial package of USD 10.5BN helped to stop the decline in reserves and calm the markets. However, the Turkish lira had already experienced a substantial decline in value against the US dollar, impacting its foreign exchange reserves (Akyuz & Boratav, 2003).

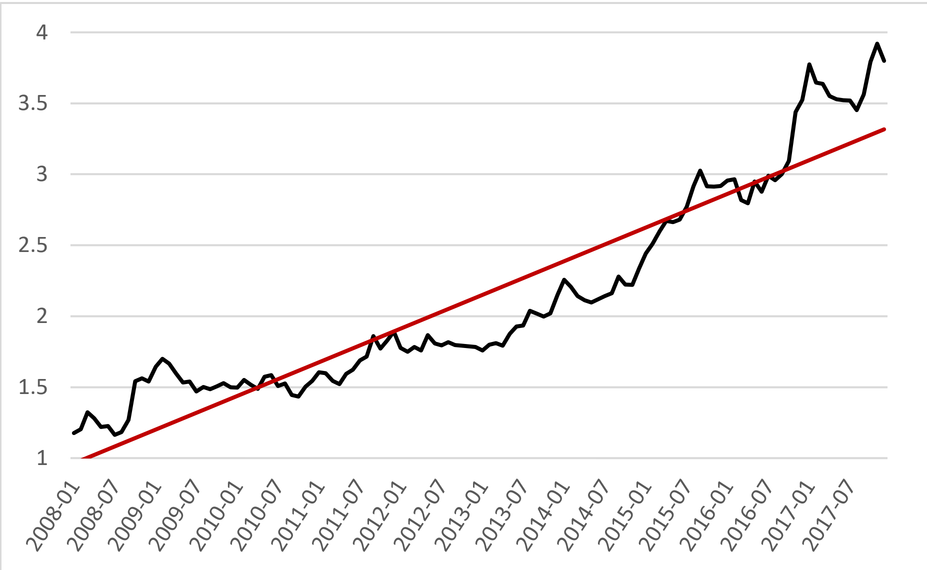
The crisis that began in 2000 continued in 2001, and the effects of the 2001 economic crisis were severe. The economic turmoil caused a significant loss of confidence in the Turkish economy. Inflation rates soared to three-digit figures. The value of the Turkish lira again experienced a sharp decline against the US dollar. The market lost many foreign investors and failed to meet the excess demand for foreign currency (Tumturk, 2019). In addition to the economic measures taken in response to the 2001 crisis, there were further developments that aimed to strengthen the Turkish economy. In November 2002, the new government came to power and promptly implemented a new budgetary discipline. Furthermore, a significant step was taken, and six zero was removed from the Turkish lira on December 31, 2004. This currency reform aimed to simplify transactions and improve the perception of the Turkish lira both domestically and internationally. The data used for this analysis is adjusted between 2001-2004 according to this change. Between 2002 and 2008, the government's efforts to control inflation, enhance financial stability, and promote economic growth contributed to the performance of the Turkish lira. In addition, negotiations began for Turkey’s accession to the EU as a member state in 2005. The prospect of EU membership created a positive sentiment towards the Turkish economy, attracting foreign investors and bolstering the value of the lira. Although the USD/TRY exchange rate that was at 1.17 in 2001 experienced a significant hike due to the impact of the crisis and reached to 1.70, it followed a more stable path as a result of positive economic developments and dropped below 1.20 again until the 2008 crisis (Akcay & Gungen, 2019). Figure 2 illustrates that the trend of the dollar remained downward during the period from 2001 to 2008.

**Figure 2.** The USD/TRY exchange rate data from March 2001 to December 2007




Another crisis broke out in 2008, prompting central banks of developed countries to set their policy rates to an all-time low to keep the market liquid (Yilmaz, 2009). The impact of this crisis on developing countries was relatively less severe, and investors sought returns in emerging markets. Looking at the situation in Turkey, the financial system was not affected by the crisis, however, the same cannot be said for the economic fundamentals which were severely impacted. For instance, production decreased, the economy contracted, and the unemployment rate reached serious levels (Temiz & Gokmen, 2009; Rodrik, 2012). In addition to the problems with economic fundamentals, notable changes were observed in the exchange rate market. The dollar rate, which declined to 1.20 levels before the crisis, broke a record and reached 1.80 in 2009. The foreign trade and the current account deficit issues, which became more pronounced in the early 2000s, continued to rise rapidly in 2010. This situation led to a rapid increase in imports, which, in turn, had a constraining effect on exports, thereby impacting the overall economy (Akcay & Gungen, 2019). However, the Turkish lira achieved to strengthen against the dollar in the end of 2010 due to significant inflows of foreign exchange. In 2013, the dollar exceeded 2 Turkish Liras for the first time, as illustrated in Figure 3, after remaining below that level for 12 years following the transition to the floating exchange rate regime in 2001. This change was influenced by serious internal issues (for example, The Gezi Park protests), which further contributed to the economic challenges faced by the country (Akcay & Gungen, 2019). Furthermore, the announcement by the US Federal Reserve (FED) regarding a potential reduction in asset purchases prompted investors to withdraw from emerging markets, including Turkey (Orhangazi & Yeldan, 2021). The value of the dollar rapidly appreciated against the Turkish lira. As shown in Figure 3, the Turkish lira weakened to 3 per USD for the first time in 2015, and Turkey has experienced another period of aggressive economic. The debate over interest rates that started in 2015 also accelerated movements in the US dollar-Turkish lira exchange rate. Moreover, Turkey's economic problems such as the increasing current account deficit, inflation reaching double digits again, and continuation of market uncertainties, have damaged foreign investor confidence in Turkey. Starting from 2016, the amount of money flowing to emerging countries such as Turkey decreased as the FED began to withdraw the money released with the outbreak of 2008 crisis. It caused the dollar to close 2016 at the level of 3.5 TL. Furthermore, in 2017, the FED's decision to gradually increase interest rates put additional pressure on the Turkish lira. The USD/TRY exchange rate, which was at 1.17 TL in early 2008, reached historical lows by the end of 2017, and the Turkish lira weakened to as low as 3.8 TL per dollar. The upward trend from 2008 to 2017 is depicted in Figure 3.

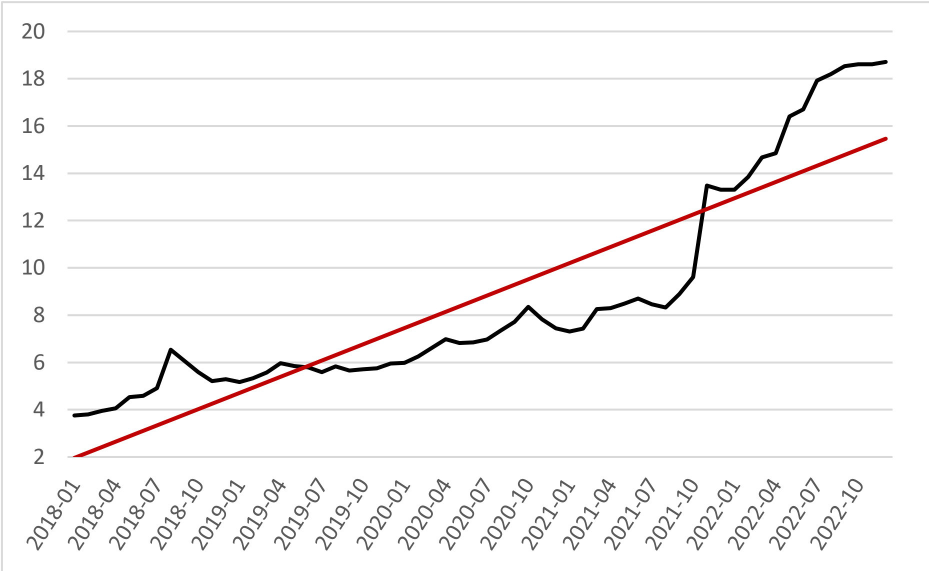
**Figure 3.** The USD/TRY exchange rate data from January 2008 to December 2017




A serious crisis hit the Turkish economy one more time in 2018 (Orhangazi & Yeldan, 2021). Turkey is not unfamiliar with exchange rate shocks and financial crises but this time it was different and not easy to explain the depreciation of the Turkish lira in economic terms. As the economy of a nation may experience a time of instability as a result of internal political issues and challenging external environments (Cehreli et al., 2017), at that time the economic challenges faced by Turkey were further compounded by internal political issues and challenging external environments (e.g., tensions between the US and Turkey, the Brunson case, the S-400 agreement, and the Syrian war). The US dollar - Turkish lira exchange rate climbed from 3.75 to 4.90 in the first five months of 2018, and then the combination of intense and difficult economic situations and political problems further led to a rapid fall in the value of the Turkish lira against the dollar up to 7.20. Moreover, the lira faced harsh US sanctions. To alleviate these problems, the interest rate was increased to 24 percent. With the release of Brunson, the dollar decreased to 5 and closed 2018 at the level of 5.29.

Despite weak economic conditions, Turkey’s monetary authorities implemented a new economic model focused on interest rate cuts. This policy shift began in 2019. The policy rate quickly decreased from 24 percent to 8.25 percent in only 12 months. However, the implementation of this model and the sharp decline in interest rates had various consequences. One significant impact was the continuation of investments that generated foreign debt, leading to a substantial increase in Turkey's total external debt. By late 2019, the total external debt had reached $440 billion, while the country's reserves amounted to only around $80 billion. Another significant concern was the persistently high inflation. Inflation has been a long-standing issue in the Turkish economy, and the widening gap between producer and consumer prices has raised concerns about the ongoing crisis. The combination of low interest rates, high inflation, and a weak exchange rate further exacerbated the challenges faced by the Turkish lira (Akcay & Gungen, 2019). Additionally, the COVID-19 pandemic occurred in 2020 had a profound impact on the global economy and the foreign exchange market. The pandemic-induced economic uncertainties led to increased volatility and risk aversion among investors, affecting currency exchange rates worldwide (Dineri & Cutcu, 2020). The Turkish lira faced significant depreciation against major currencies, particularly the US dollar, as investors sought safer assets (Unal et al., 2020). Since then, the value of the Turkish lira has been on a continuous decline, and currently, the US dollar has been traded at the 18s levels, breaking a record day by day. The fluctuations in the USD/TRY exchange rate from 2018 to 2022 can be observed in Figure 4, highlighting the magnitude of the changes over this period.

**Figure 4.** The USD/TRY exchange rate data from January 2018 to December 2022




As discussed above, the USD/TRY exchange rate has shown an overall upward trend. This trend can be attributed to various economic challenges faced by the Turkish economy during the studied period as these economic challenges play a significant role in shaping the exchange rate dynamics between the two currencies. To summarize, these challenges include high inflation rate, large current account deficit, trade deficits, the balance of payments, low savings rate, price fluctuations, uncertainty regarding the future, disruption of the financial sector's stability caused by high inflation, excessive reliance on borrowing for economic growth, fluctuations in the value of the Turkish Lira, exchange rate instability, and high unemployment rates (Cinel, 2019). In conclusion, economic factors have a significant influence on the Turkish economy and the foreign exchange market, thus it is crucial to closely monitor and consider these factors when interpreting the volatility in the foreign exchange market.

# CHAPTER 4

# TECHNICAL NOTES ON TEST TECHNIQUES FOR BUBBLE DETECTION

As we adopt the method by Pavlidis et al. (2017) that looks at whether the deviations of future spot rate from forward rate present explosive behavior by right-tailed unit root tests, this chapter is devoted to providing some technical notes on test techniques for identifying explosive behavior in a time series.

## 4.1. UNIT ROOT TESTS FOR BUBBLES

Unit root tests are one method to test for explosive dynamics in time series (see Gurkaynak, 2008; Homm & Breitung, 2012). These tests generally compare a null hypothesis of a unit root (i.e., non-stationary) against a stationary alternative which is located on the left side of the probability distribution. With the growing interest in the detection of rational bubbles, many researchers have applied various unit root tests in their analysis. However, these early testing procedures were weak and often resulted in inconclusive results. The 2007-2008 financial crisis renewed interest in bubbles and their global consequences, providing researchers with a rich environment for further empirical research (Wöckl, 2019).

Recently, Phillips, Wu, and Yu (2011), Phillips and Yu (2011), and Phillips, Shi, and Yu (2015a) proposed a convincing series of testing methods for bubble detection as well as the starting and ending points of bubble episodes. These methods have quickly gained popularity and have become increasingly widely used in empirical studies. They only require price time series and build on the assumption that prices usually follow a random walk, which means that they have a unit root. However, this assumption no longer holds if they exhibit substantial deviations from their fundamental values. Instead, the series may be characterized by explosive behavior or bubble existence. (Bohl et al. 2013). Following Phillips et al. (2015a), a random walk process is considered with an asymptotically negligible drift, and it can be written as follows:

$$y_t = dT^{-n} + \theta y_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim iidN(0, \sigma^2), t = 1, \ldots, T, \tag{18}$$

Where d is a constant term, T is the total number of observations, and the parameter n is a localizing coefficient that controls the magnitude of the drift as T approaches infinity. With n >1/2, the order of magnitude of $y_t$ is the same as that of a pure random walk (i.e., the null of the SADF procedure). $\varepsilon_t$ is the error term with constant variance that has mean zero (0). As is evident from the equation, their recommended empirical regression for bubble detection involves an intercept but no fitted time trend.

As is the case with all testing procedures, correctly defining the model is crucial for conducting tests for explosiveness in the sample. To achieve that, the above model is commonly supplemented with transient dynamics just as in the standard ADF unit root testing for stationarity. More specifically, with $r_1$ and $r_2$ denoting fractions of the total number of observations (T), it is supposed that the regression sample starts from $r_1$ and ends at $r_2$. Hence, the (fractional) window size of the regression becomes $r_2 = r_1 + r_w$ and $r_w > 0$. This empirical regression model is given by

$$\Delta y_t = \alpha_{r_1-r_2} + y_{r_1-r_2} y_{t-1} + \sum_{i=1}^{k} \varphi_{r_1-r_2}^{t} \Delta y_{t-i} + \varepsilon_t \quad (19)$$

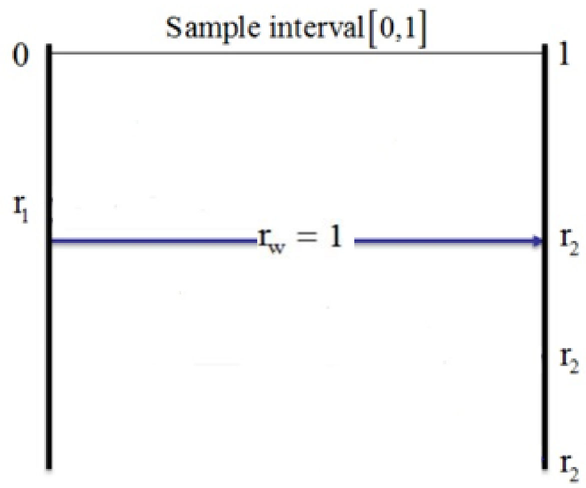
where Δ denotes the first difference operator, $y_t$ denotes a time series process under examination at time t, k is the transient lag order, and $\varepsilon_t$is the error term. The key parameter of interest here is $y_{r_1,r_2}$and we formally test for H0: $y_{r_1,r_2}$=0 under the null hypothesis and H1: $y_{r_1,r_2}$>0 (explosive behavior) under the alternative hypothesis. The ADF test statistic based on this null can be described as follows

$$ADF_{r_1}^{r_2} = \hat{y}_{r_1,r_2} / s.e.(\hat{y}_{r_1,r_2}) \quad (20)$$

#### 4.1.1. The Standard ADF Test

To obtain the statistic in Equation 20 for the ADF test, the regression shown in Equation 19 is estimated using all available observations, where $r_1$ is set to 0 and $r_2$ is set to 1.

**Figure 5.** Illustration of the standard ADF procedure




Under the null of a unit root, the ADF test statictics have the following limit distribution,

$$\frac{\int_0^1 W dW}{\left(\int_0^1 W^2\right)^{1/2}} \tag{21}$$

Where W denotes the standard Brownian motion (or the standard Wiener process). The test is a process that requires comparing the ADF statistic with the right-tailed critical value from its limit distribution (Vasilopoulos et al., 2022). In this setting where $r_1$ and $r_2$ are set at 0 and 1, respectively, the alternative hypothesis suggests exuberance throughout the sample (Phillips et al., 2015a). If the ADF test statistic is greater than the corresponding critical value, then the alternative hypothesis is accepted instead of the unit root hypothesis. Consequently, the standard ADF test cannot identify regime changes. It exhibits low statistical power when there are boom-bust episodes. Namely, nonlinear dynamics, such as the ones seen in periodically-collapsing speculative bubbles, often result in falsely identifying a state of stationarity even when the process being studied is actually explosive (see Evans 1991).

### 4.1.2. The Supremum ADF (SADF) Test

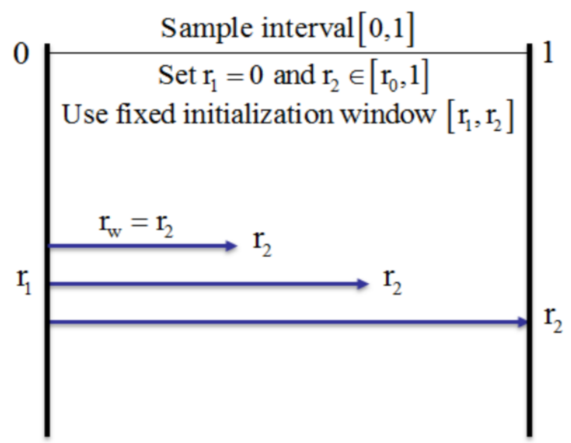
Phillips et al. (2011) derive a new unit root test which is called the supremum Augmented Dickey-Fuller (sup ADF or SADF). They define financial exuberance in terms of explosive autoregressive behavior and evaluate the empirical evidence of exuberant by using forward recursive regression tests. These forward recursive regressions are performed by using subsamples of data on a period-by-period basis rather than the full sample. The

SADF test proposes a recursive procedure that repeatedly estimates the ADF statistics with a fixed starting point and a forward expanding window. The sup ADF procedure is defined as

$$SADF(r_0) = \sup_{r_2 \in [r_0, 1]} ADF_0^{r_2} \quad (22)$$

Where $r_0$ is the minimum window size which is set by the user. The first observation in the data is set as the starting point of the estimation window, $r_1$, and the starting point stays fixed to the first observation through the procedure, $r_1$=0. Moving forward, the end of the estimation window, $r_2$, is set according to the user-specified minimum windows size, $r_0$, which means $r_w$ = $r_2$. Finally, the regression is recursively estimated by adding one observation at a time while extending the window size, $r_2$, from $r_0$ to one (Caspi, 2017; Pavlidis et al., 2018). Each estimation generates an ADF statistic denoted as $ADF_0^{r_2}$. It is important to note that the final estimation runs on the entire sample (i.e., $r_2$ = 1 and the statistic will be $ADF_0^1$). Thus, the SADF statistic is defined as the supremum value of the $ADF_0^{r_2}$ sequence for $r_2 \in [r_0, 1]$. The sample sequences of the SADF test are illustrated in Figure 6.

**Figure 6.** Illustration of the SADF procedure




Under the null hypothesis, the SADF statistic has the following limit distribution:

$$\sup_{r_2 \in [r_0, 1]} \frac{\int_0^{r_2} W dW}{\int_0^{r_2} W^2} \quad (23)$$

Like the standard ADF test, if the SADF statistic is larger than the relevant critical value obtained from its limit distribution, it is concluded that the unit root hypothesis claiming that the series do not display explosiveness is rejected. However, unlike the standard ADF test which looks for the existence of explosive dynamics throughout the whole sample, the alternative hypothesis of the SADF test focuses on some part(s) of the sample in search of explosive dynamics.

Simulation experiments conducted by Homm and Breitung (2012) display satisfactory results of the SADF in detecting one or two bubble periods. However, Phillips et al. discuss (2013) that although the SADF procedure is capable of estimating the first date of the first bubble when there are two bubble episodes, it may not be able to detect the occurence of the second bubble. This is because the second bubble might be dominated by the first bubble in the case of two bubble episodes, and the second bubble may go unnoticed.

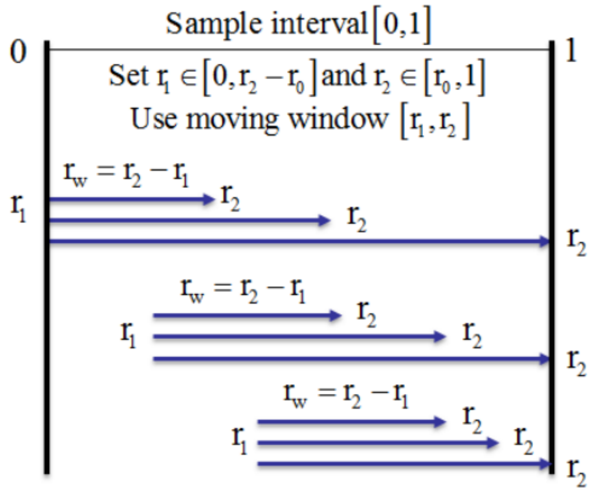
#### 4.1.3. The Generalized SADF (GSADF) Test

Phillips et al. (2015a) introduce a new unit root test called the generalized SADF (GSADF) test, specifically designed to detect multiple bubble episodes in time series data. This new methodology is an extension of the SADF test and relies on recursive right-tailed ADF tests like the SADF test. However, the GSADF test has an important feature that makes it more flexible and powerful than the SADF test when dealing with multiple bubbles in the data. This feature allows the GSADF test to cover a larger number of subsamples by changing both the starting point and the end of recursion, which clearly enhances the test's discriminatory power (Pavlidis et al., 2019). The GSADF test statistic repeatedly calculates the right-tailed ADF test with varying the start and end points of a sub-sample period (Celik et al., 2019). Formally, it can be written as follows:

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ ADF_{r_1}^{r_2} \right\} \tag{24}$$

Where $r_1$ is the start point, and $r_2$ is the end point. While the end point, $r_2$, ranges from $r_0$ (the minimum windows size) to 1, the starting point, $r_1$, ranges from 0 to $r_2 - r_0$. The GSADF regression is the largest ADF regression over range of $r_1$ and $r_2$ (Phillips et al., 2015). Figure 7 illustrates the sample sequences of the GSADF test.

**Figure 7.** Illustration of the GSADF procedure




Under the null hypothesis, the GSADF statistic has the following limit distribution:

$$\sup_{r_2 \in [r_0,1], r_1 \in [0, r_2 - r_0]} \left\{ \frac{\frac{1}{2} r_w [W(r_2)^2 - W(r_1)^2 - r_w] - \int_{r_1}^{r_2} W(r) dr [W(r_2) - W(r_1)]}{r_w^{1/2} \left\{ r_w \int_{r_1}^{r_2} W(r)^2 dr - [\int_{r_1}^{r_2} W(r) dr]^2 \right\}^{1/2}} \right\} \quad (25)$$

Where $r_w$ = $r_2$ - $r_1$ is the size of the expanding window, and W denotes a standard Wiener process. Again, if the GSADF test statistic is larger than the right tail critical value from its limit distribution, we can reject the unit root hypothesis in favor of explosive behavior.

**Table 1.** A summary of the tests' null and alternative hypotheses according to Phillips et al. (2015a)

| Test | Null hypothesis | Alternative hypothesis |
|---|---|---|
| ADF | Unit root | Explosive process |
| SADF | Unit root | Single periodically collapsing bubble period |
| GSADF | Unit root | Multiple periodically collapsing bubbles |

Source: (Caspi, 2017)

## 4.2. DATE-STAMPING STRATEGIES

If the GSADF test rejects the unit root hypothesis, the series under consideration displays explosiveness. As part of the GSADF, Phillips et al. (2015) also introduce a date stamping strategy that allows researchers identify a chronology of episodes of price explosiveness. The strategy is based on the Backward Sup ADF (BSADF) which is shown as

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} BADF_{r_1}^{r_2} \quad (26)$$

Let $r_e$ and $r_f$ denote the origination and termination dates, respectively. The origination date of the bubble is the first observation where the BSADF statistic is above its critical value, and then the termination date is the first date after which the BSADF statistic is below its critical value again (Pavlidis et al., 2018).

Specifically, the origination and termination dates can be defined as follows:

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) > scu_{r_2}^{\beta_T} \right\} \; and \; \hat{r}_f = \inf_{r_2 \in [\hat{r}_e, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) < scu_{r_2}^{\beta_T} \right\} \quad (27)$$

Where $scu_{r_2}^{\beta_T}$ denotes the $100\beta_T\%$ critical value of the SADF for $[r_2 T]$ observations, and $\beta_T$ denotes the chosen significance level. The consistency of the SADF date-stamping strategy with a single bubble period in $y_t$ is established in Phillips et al. (2011), and the consistency of the GSADF date-stamping strategy in the presence of one or two bubble periods is established in Phillips et al. (2015a,b).

## 4.3. SOME TECHNICAL DETAILS

In general, the bubble detection results may differ according to a number of factors. Particularly, the list includes the use of the full sample or subsamples, the choice of the minimum window size, the lag length, and model specification under the null hypothesis (Vasilopoulos et al., 2022). As is evident from the key difference between the SADF and the GSADF test, the choice of whether the empirical test will be applied to a subsample of data or the full sample plays an important role in assessing the evidence of bubbles. With regard to the minimum window size, Phillips et al. (2015a) state that the asymptotic distribution of the GSADF test statistic relies on the minimum window size denoted as

$r_0$. In practice, the minimum window size should be set according to the sample size $\mathrm{T}$. When $\mathrm{T}$ is small, the minimum window size must be large enough to ensure adequate initial esmation with sufficient observations. When $\mathrm{T}$ is large, the minimum window size can be set to be a smaller number so that the test can identify an early explosive episode (Phillips et al., 2012). For this empirical analysis, we follow the rule of Phillips et al. (2015a), $r_0 = 0.01 + 1.8\sqrt{\mathrm{T}}$, to select the appropriate window size. This setting is recommended for empirical use due to its satisfactory size and power performance. Optimal lag length is also important. If the lag length is too large, it causes severe size distortion and reduces the power of both the GSADF and the SADF tests. The lag length for the test statistics should be chosen based on the autocorrelation structure of the data. A common approach is to apply the Akaike Information Criterion (AIC) or the Bayesian Information Criterion (BIC) to determine the optimal lag length. For monthly data, a common starting point for the lag length is 12, which represents one year of lag. However, it is important to note that this may not be the optimal lag length for all datasets. It should be determined based on the characteristics of the data and the research question being investigated. According to our other simulation experiments, the results do not appear very sensitive to the lag length selection. Consequently, we apply the AIC criterion and set the lag length to 12. The last factor that is worth mentioning is model specification under the null. Phillips et al. (2014) examine different versions of the null and alternative hypotheses in the right-tailed unit root test of Phillips et al. (2011). Under simulations, the regression models are built on various specifications, such as including or excluding an intercept, or a trend. They demonstrate that model specification can influence both the finite sample and the asymptotic distributions and recommend an empirical model specification with an intercept.

# CHAPTER 5

# DATA DESCRIPTION AND EMPIRICAL RESULTS

Data on nominal spot and forward exchange rates (1, 3, and 6 months maturities) are obtained from Thomson Reuters DataStream for the empirical application. Since the US dollar is the dominant currency (Onen & Yurdagul, 2022), the US Dollar exchange rates (USD/TRY) are used in our analysis. Our sample covers monthly data spanning the periods from March 2001 to December 2022 with 262 observations. The use of monthly data is chosen to rule out short-term price movements. In other words, high frequency series would not be useful for our purposes as small deviations in the data would come back to the equilibrium level in a short time and is not useful in bubble detection. We restrict our sample to these periods since the Central Bank of the Republic of Turkey adopted the floating exchange rate regime on February 22, 2001.

In order to observe the overall patterns, we depict USD/TRY spot and 1-month forward exchange rates over the sample periods in Figure 8 and 9. When we look at spot and forward movements, both series seem to exhibit a high degree of similarity. The depreciation of Turkish Lira against the dollar can be clearly seen. Turkey's economic problems have been building especially since 2013-14, and some deep problems in economic indicators are believed to have dramatically affected the price of Turkish lira against U.S dollar (Keceligil, 2019). The list includes high inflation, lower interest rate, rising borrowing and correspondingly rising loan defaults. It is clearly seen that there is an increasing trend and some recent massive volatile behavior in the FX market since 2018. Moreover, the outbreak of Covid pandemic put increasing pressure on the lira. Another factor which may be responsible for those large movements could be speculation. The natural question is: Are there any speculations causing bubbles (speculative bubbles) in USD/TRY exchange rate or are the changes in fundamentals responsible for excessive movements in the exchange rate?

**Figure 8.** The US dollar- Turkish lira spot exchange rate from March 2001 to December 2022

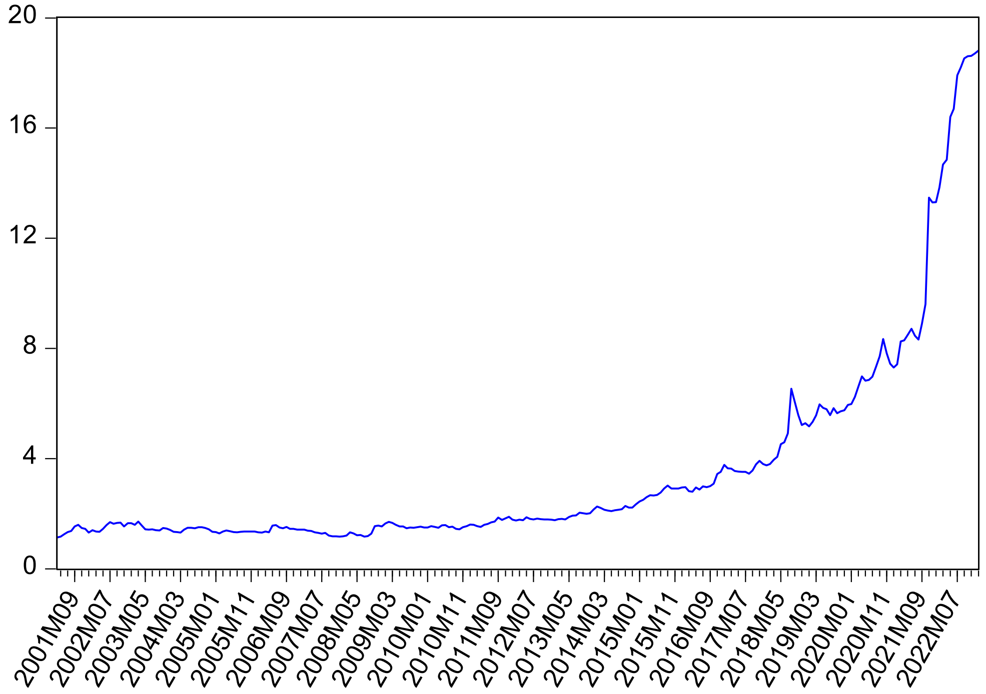
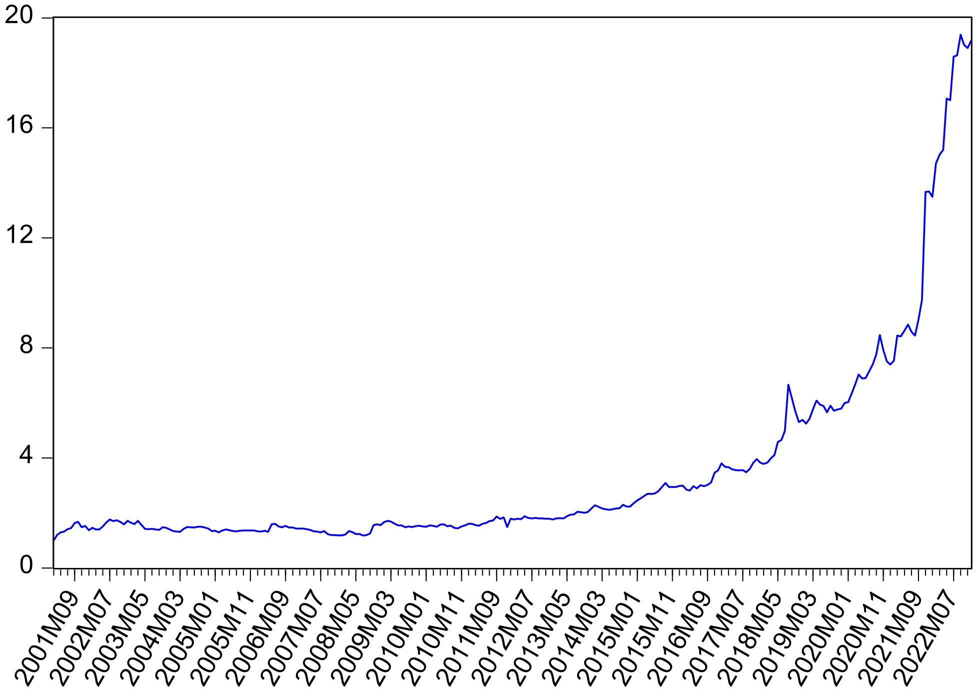



**Figure 9.** The US dollar- Turkish lira forward exchange rate from March 2001 to December 2022



Before starting the analysis, descriptive statistics on spot and forward rates are given in Table 2 below.

**Table 2.** Descriptive Statistics

| | **Spot** | **Forward** |
|---|---|---|
| Observation | 262 | 262 |
| Mean | 3.483453 | 3.468224 |
| Median | 1.783100 | 1.782096 |
| Maximum | 18.81490 | 19.39400 |
| Minimum | 1.000000 | 1.000000 |
| Std. Dev. | 3.763358 | 3.743681 |
| Skewness | 2.579576 | 2.638432 |
| Kurtosis | 9.547096 | 10.00155 |
| Jarque-Bera | 758.5044 (0.000000) | 839.1314 (0.000000) |

It is seen that the spot and forward rates exhibit volatile market dynamics with a high standard deviations. For the overall sample period, the spot rate is at around 3.48; the forward rate is at around 3.47 on average. In addition, both of the series are skewed to the right in constrast to normal distribution. According to the kurtosis coefficient, there is a leptokurtic distribution. Lastly, the Jarque-Bera normality test results reveal non-normal distribution of the series.

Following Pavlidis et al. (2017), ADF, SADF, and GSADF tests are separately applied to the logarithms of USD/TRY spot ($s_t$) and 1-month forward ( $f_{t,1}$) rates. The results are presented in Table 3. As seen, we reject the null hypotheses of unit root against explosive behavior (bubble) for both series across all tests.

**Table 3.** Right-tailed Unit Root Tests

| Results of Unit Root Tests | | | |
|---|---|---|---|
| | $s_t$ | $f_{t,1}$ | Monte Carlo Based Critical Values |
| ADF | 3.5767 | 2.0087 | -0.0578 |
| SADF | 3.8845 | 3.4299 | 1.3953 |
| GSADF | 3.9732 | 4.0701 | 2.1700 |

NOTE: The table reports unit root tests statistics for the US dollar- Turkish lira spot rate, forward rate. The finite-sample 95% critical value for the GSADF tests is obtained using Monte Carlo simulation with 2000 random walk processes. The minimum window has 32 observations.

In order to date-stamp the starting and ending periods of explosive behaviors in these series, backward SADF sequences are obtained and compared with %95 SADF critical value sequence. These sequences are depicted in Figure 10. As seen there is no explosive behavior in spot rate before December 2014. Since then, we observe two (multiple) bubble periods. The first bubble starts to occur at the end of 2014 and bursts at around May 2016 and the second starts at August 2016 and does not collapse until the end of sample period.

**Figure 10.** The sequence of BSADF statistics for the log of the spot market and the forward market

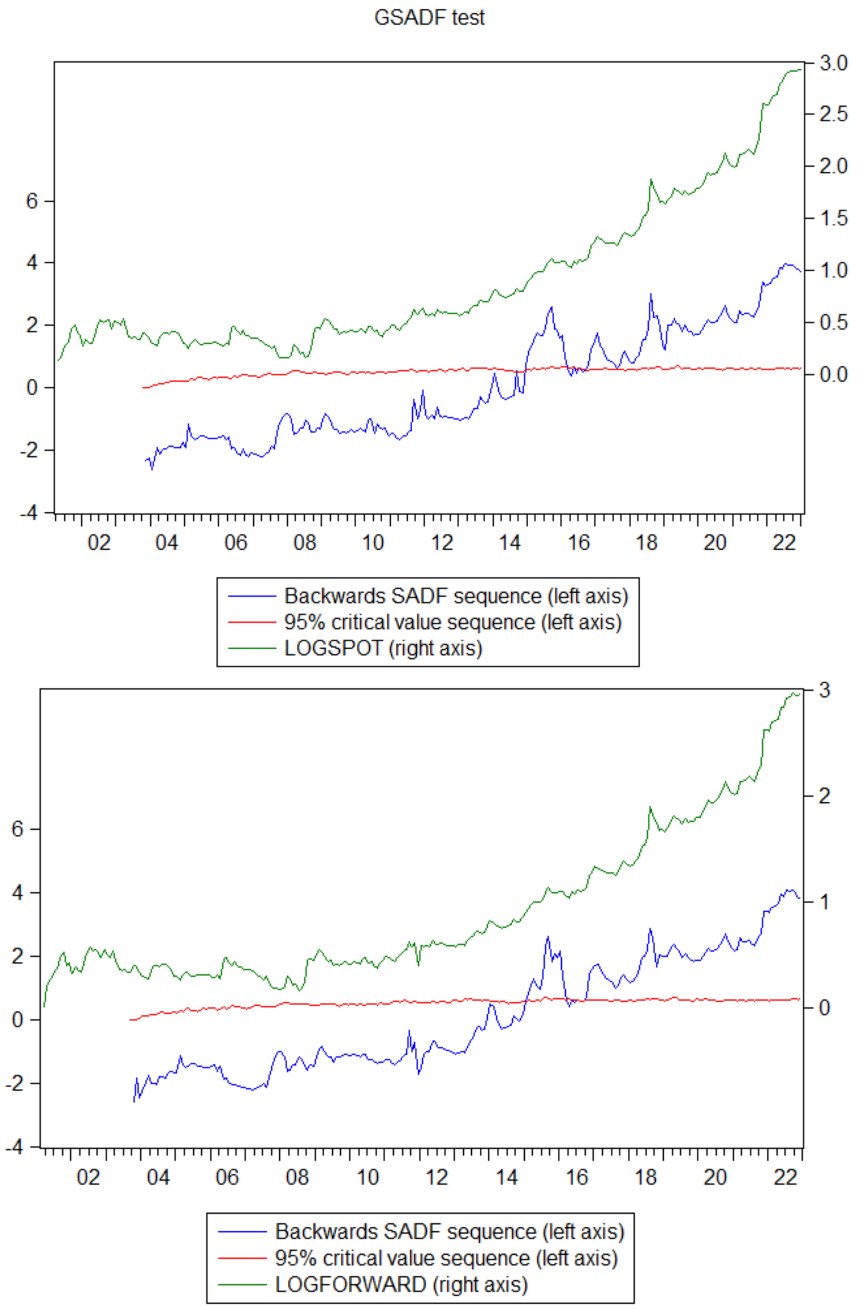
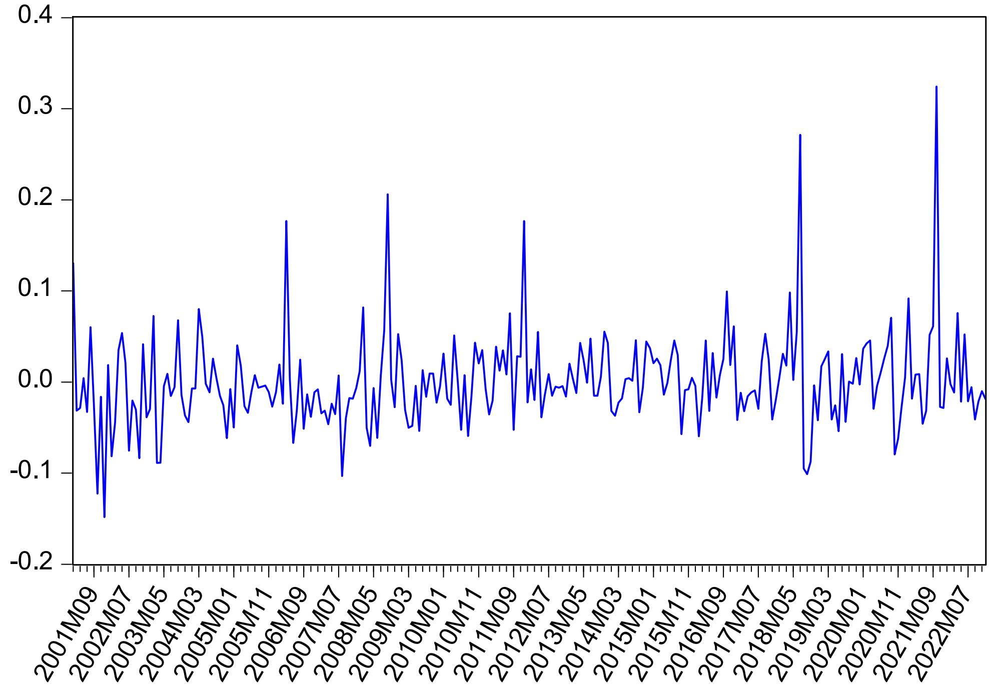


**Figure 11.** The difference between the logarithm of the future US dollar - Turkish lira spot rates and the logarithm of the forward rate, $s_{t+1}$-$f_{t,1}$, from March 2001 to December 2022




The next step is to examine whether these explosive behaviors are driven by rational speculative bubbles. Given the definition of rational bubbles, it is essential to consider both the possibility of bubble formation and changes in fundamentals to ensure accurate conclusions. In our context, if we focus only on explosive behaviors in spot rates and neglect the fundamentals, the results would be inconclusive. On this basis, we follow Pavlidis et al. (2017)'s approach offering a way to consider both fundamentals and market expectations through the monitoring of spot and forward rates. Since forward rates are thought of as representing the movements in fundamentals, this approach allows us a more comprehensive understanding of potential bubble-like patterns. Following the lead of Pavlidis, we apply the SADF and GSADF tests to the log difference of spot and forward rates ($s_{t+1,t+3,t+6}$ - $f_{t,1,3,6}$, respectively). Table 4 reports the results. Upon examining the results, while we reject the null hypothesis of no explosiveness for the spot rates, we fail to reject the null for the differences between spot and forward rates. This implies that there is evidence of explosive behavior in the spot rates, but not in the differences between spot and forward rates. These contrasting outcomes highlight the importance of distinguishing between fundamentals and bubble formations when studying the dynamics of explosiveness in the financial markets.

**Table 4.** Unit Root Tests for 1,3, and 6 months

| Results of Unit Root Tests | | | | | |
|---|---|---|---|---|---|
| | $s_t$ | $s_{t+1} - f_{t,1}$ | $s_{t+3} - f_{t,3}$ | $s_{t+6} - f_{t,6}$ | Monte Carlo Based Critical Values |
| ADF | 3.5767 | -14.9745 | -3.2040 | -3.0377 | -0.0578 |
| SADF | 3.8845 | -2.2041 | -1.5967 | -0.6482 | 1.3953 |
| GSADF | 3.9732 | -0.2075 | -0.6172 | 0.2983 | 2.1700 |

NOTE: The table reports unit root tests statistics for the difference between the logarithm of US dollar-Turkish lira spot rate and the logarithm of forward rate $s_{t+n}$-$f_{t,n}$ with n=1,3, and 6. The finite- sample 95% critical value for the GSADF tests is obtained using 2000 simulations. The minimum window has 32 observations.

In order to further look at the time-varying sequences for date-stamping, backward SADF and critical value sequences for $s_{t+1}$ - $f_{t,1}$; $s_{t+3}$ - $f_{t,3}$; $s_{t+6}$ - $f_{t,6}$ are depicted respectively in Figures 12, 13 and 14. These figures demonstrate that there is no evidence of speculative bubble formation in the USD/TRY exchange rate over the sample period. Thus, the alignment between the explosive behaviors in forward rates and spot rates suggests that the fluctuations in the USD/TRY exchange rate series actually seems to be driven by the excessive movements in forward rates, i.e. fundamentals.

**Figure 12.** The sequence of BSADF statictics for $s_{t+1} - f_{t,1}$

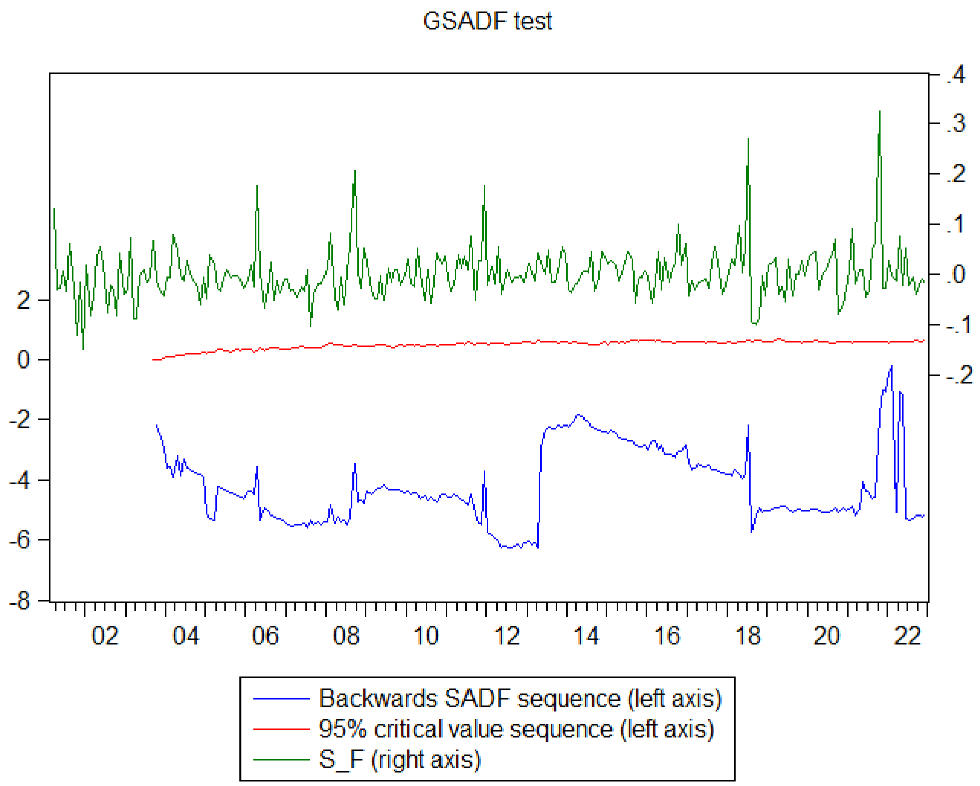


**Figure 13.** The sequence of BSADF statictics for $s_{t+3} - f_{t,3}$

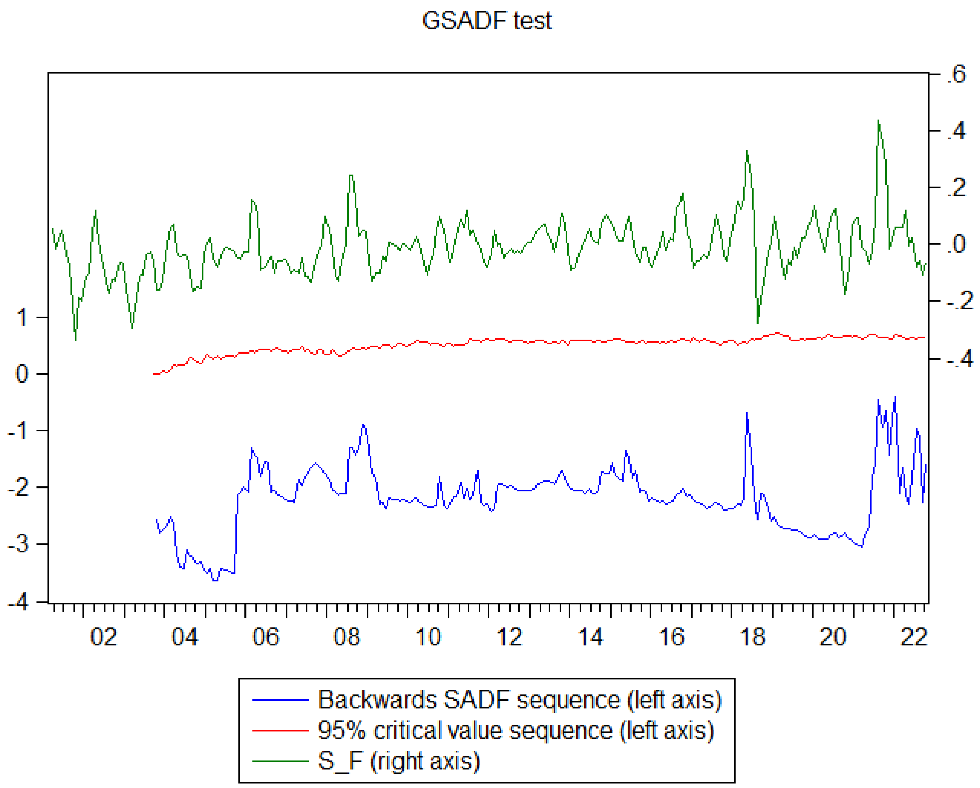
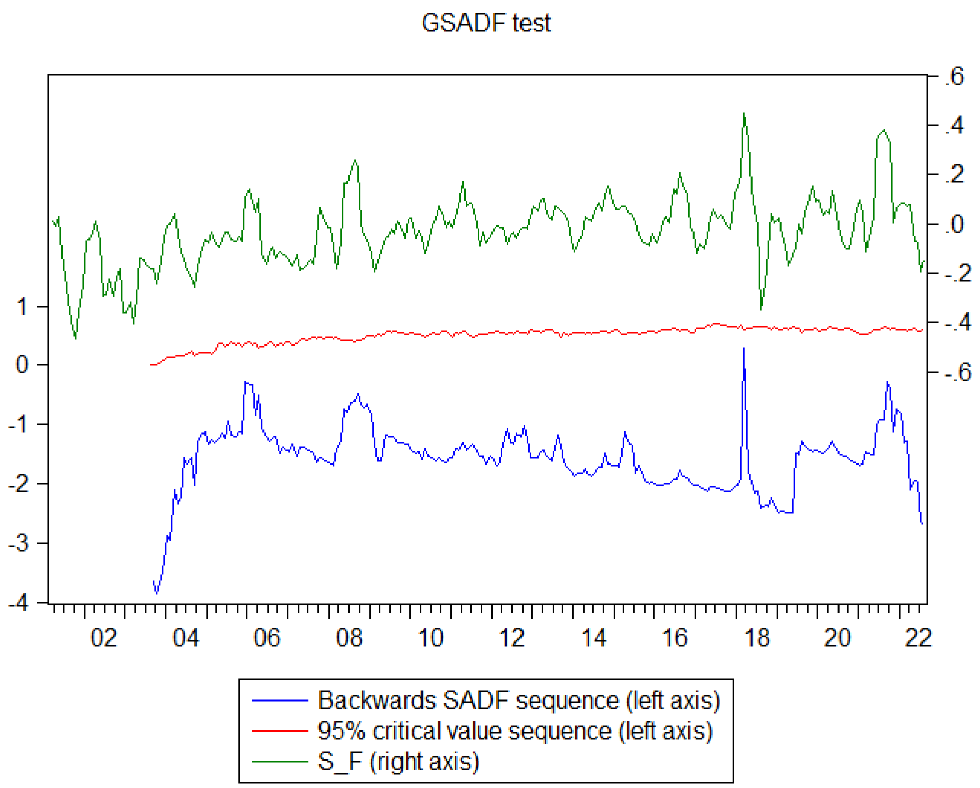



**Figure 14.** The sequence of BSADF statictics for $s_{t+6} - f_{t,6}$



# CONCLUSION

Volatile exchange rates greatly affect monetary and financial stability. For that reason, exchange rate fluctuations have long been an outstanding research topic in international finance. It is essential to identify the actual cause behind explosive dynamics in exchange rates because they may occur for various of reasons, such as speculative bubbles or exchange rate fundamentals. In this study, we examine whether US Dollar-Turkish Lira exchange rate form rational speculative bubbles over the periods of 2001-2022. There are a couple of empirical studies investigating bubble formation in USD/TRY exchange rate. However, the previous studies on USD/TRY exchange rate exhibit an explosive behaviour and interpret this as evidence of bubble formation. However, explosiveness in asset prices is not sufficient condition for bubble formation but it is also necessary to check if economic fundamentals are explosive or not since explosiveness in asset prices might be triggered by explosiveness in fundamentals.

Another challenge for empirical bubble studies is to specify a model for fundamentals. Accurate identification of bubble formation depends mainly on correct specification of model for fundamentals because testing the null hypothesis of ‘no bubble’ turns into testing the null of correct model specification for fundamentals (joint hypothesis problem). Hence, rejection of the null may suggest either the existence of bubble or model misspecification. Nonetheless, one can never be certain what fundamental factors are the main drivers of an asset price given model uncetainty. At this juncture, Pavlidis et al. (2017) develop a framework, which uses information from currency derivative markets, without having to define specific model for fundamentals in order to detect rational bubbles in asset prices. The underlying idea behind their framework is that if the forward exchange rate provides an unbiased forecast of the future spot exchange rate (unbiased forward rate hypothesis holding), then explosive deviations between the forward (or future) price and the future spot price will point to nothing but periodically collapsing bubbles. Therefore, the differences between the two rates exhibiting explosive movements can be attributed to the presence of rational bubbles.

This thesis adopts the empirical framework by Pavlidis et al. (2017) to investigate whether there are any rational bubbles in US dollar-Turkish Lira exchange rate. To this end, this study applies GSADF tests to the difference between the forward prices and the future spot rates.

Although the spot rate displays the episodes of explosive behavior, the results of this study suggest that there is no evidence of rational ‘speculative’ bubbles in the US dollar-Turkish lira over the period of 2001 to 2022. As a result, the explosiveness in nominal USD/TRY exchange rates seems to be driven by the excessive movements in forward rates viewed as the representative of the expectations of market participants about the underlying fundamental factors.

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