



Fluctuations in Electricity Prices and the Identification of Bubbles in Italy during COVID-19

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Abstract: The main objective of this study is to determine whether explosive behavior exists in Italian electricity prices by analyzing data from January 2020 to December 2021. To achieve this, three econometric methods for detecting bubbles have been used. These methods are the right-tail Augmented Dickey-Fuller (ADF) test, the Sequential Augmented Dickey-Fuller (SADF) test, and the generalized up Augmented Dickey-Fuller (GSADF) test. The ADF test detected no explosive behavior in Italian electricity prices, whereas both the SADF and GSADF tests indicated explosive behavior. Furthermore, the SADF and GSADF tests identified specific periods of explosive behavior characterized by significant price fluctuations.

Several policy recommendations to address this issue arise: introducing stabilizing price mechanisms to prevent consumers from facing unaffordable price hikes; another proposed method is diversifying energy resources, specifically by promoting renewable energy to reduce reliance on fossil fuels, whose prices are highly volatile. In addition to these changes, enhanced market monitoring and regulatory capabilities could help ensure fair competition, transparent pricing, and prevent market manipulation. Furthermore, demand-supply management programs during periods of peak price volatility and long-term contracts would provide significant stability and predictability, thereby creating favorable conditions for producers and consumers alike.

Keywords: Bubbles, Electricity Price, SADF, GSADF, GARCH.

1. Introduction

This study examines the presence of bubbles in energy prices (EPs). Bubbles occur when the price of a good exceeds its intrinsic value (Stiglitz). Conversely, bubbles burst when buyers perceive that further price increases are unlikely, as demand declines with lower prices (Khan & et al.). Similarly, commodity price bubbles are characterized by a sudden uptick, successive ballooning, and a swift collapse (Lind). Furthermore, expected price fluctuations around their fundamentals demonstrate explosive behavior. The EPs considered in this study include West Texas Intermediate Oil (WTI), Heating Oil Price (HOP), Natural Gas Price (NGP), Coal Price (CLP), Brent Oil Price (BOP), and Liquefied Natural Gas (LNG). The close relationship between energy prices and the global economy has attracted significant attention from policymakers and stakeholders over the past few decades (Lind). These energy bubbles are typically characterized by a cyclical pattern of growth followed by recession (Brunnermeier). Global energy prices tend to fluctuate in a cyclical pattern, driven by periods of growth and decline, with significant impacts on the global economy. This was particularly evident during the 2007–2009 global recession (Khan & et al.). Commodity price bubbles were also notable during the Great Depression of 1929 (Su & et al.). According to Khan et al. (Alessandrini & Petrella) Volatility in EPs remains a major challenge for both exporting and importing countries. Falling exchange rates tend to reduce costs, leading to wage increases for average consumers and boosting their overall spending power (Su & et al.). Similarly, due to conflicts, political disruptions, the 2008 Global Financial Crisis (GFC), and the rise of COVID-19, EPs have been on the rise. When the pandemic started, EPs plummeted to levels that hurt the global economy, with oil prices even going negative. Therefore, studying the explosive behavior of EPs is crucial, as they have both direct and indirect effects on financial markets, consumers, and the general economy.

EPs, which were in steady demand in emerging countries during the 2000s, remain in consistent demand. However, the onset of the recession in 2008 led to a decline in demand due to an uncertain economic outlook.

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Furthermore, the transition to environmentally friendly energy alternatives is expected to reduce demand for fossil fuels, thereby influencing EPs ([Khan & et al.](#)). Before the economic downturn, the energy sector was subject to unregulated international derivative trading, which may have contributed to the formation of EP bubbles ([Khan et al.](#)). Subsequently, sluggish economic growth in emerging economies, particularly China, may have played a significant role ([Sharma & Escobari](#)). A narrowing supply-demand gap, driven by concerns over energy security, was a strong factor influencing EPs. Additionally, disruptions in the international energy market in recent years have been severe, with notable consequences ([Khan & et al.](#)). For example, in 2006, uncertainty about the future of oil markets and the development of new long-term projects led to increased volatility. EPs also experienced uncertainty from 2014 to 2016.

However, partly due to the surplus of energy on the international market at the time, the slow global economic growth led to reduced EPs. Uncertainty surrounding energy demand, exacerbated by the trade war between China and the U.S. and tense relations between Iran and the U.S., contributed to the collapse of EPs as energy demand plummeted due to lockdowns and border closures during the COVID-19 pandemic. Before the COVID-19 pandemic, disagreements among major oil producers in the global energy market had already influenced prices ([Perifanis](#)). The pandemic exacerbated this situation, resulting in a 50 percent reduction in EPs in March 2020 and plunging oil prices into a crisis zone, followed by a sharp decline in demand. The energy market experienced a slight recovery after restrictions were eased and OPEC implemented production cuts, resulting in a modest increase in oil prices. Additionally, NGP and LNG prices rebounded in 2021 as the global economy began to recover. Thus, the explosiveness of EPs is especially significant in the context of COVID-19.

This work may contribute to existing literature in several ways. First, it identifies bubbles in EPs and explores their underlying factors, reflecting the relationship between EPs and structural or underlying economic and political events. During this study, EPs exhibit multiple fluctuation episodes followed by bubble processes. Not only are EPs susceptible to policy changes and structural breaks, but these factors also attract speculation that sparks bubbles in the global energy market. Therefore, explosiveness and its causes are central topics in this paper. Second, the paper comprehensively considers the main energy sources, which are crucial for sustainable economic development ([Alessandrini & Petrella](#)).

It provides information on different types of EPs and bubble simulations that can be useful to policymakers in managing energy price spikes. Finally, the econometric methods employed in this study, namely the Supremum Augmented Dickey-Fuller (SADF) and GSADF tests, have been shown to outperform traditional methods. Traditional methods for bubble detection often lack power and have unstable windows, making them less suitable for detecting bubbles. In contrast, the SADF and GSADF tests have wider detection windows, adapting to the sample and detecting bubbles in both the entire sample and sub-samples. These methods are appropriate for detecting compound bubbles in EPs. The findings reveal several bubbles in EPs at key points in time. The most critical subperiod, 2007–2008, coincided with a bubble driven by strong economic growth, which caused EPs to rise and then burst during the 2008 financial crisis ([Fioretti & Otranto](#)). Another bubble formed around 2014–2015 due to low economic growth and a shrinking oil supply, which reduced EPs. These results are valuable for governments, investors, regulators, and economists in understanding early warning signs ([Grasso & et al.](#)).

EPs are closely related to the international commodities market, and fluctuations in EPs can have contagious effects globally. Therefore, a bubble in the energy market can signal a potential economic decline, serving as a warning for investors and policymakers. The energy market's interaction with the commodities market means the explosive nature of EPs can spread globally. Hence, this analysis makes a valuable contribution, and the identified bubble parameters can be further leveraged to mitigate the risk of a global energy market collapse. The results also inform pre-bubble and post-bubble strategies ([Homm & Breitung](#)). The occurrence of EPs at critical moments offers regulators and policymakers an opportunity to take preemptive measures. This paper presents a test for the presence of bubbles in Italian electricity prices, compares it with traditional ADF tests, and identifies the most suitable method for detecting bubbles.

The importance of this study lies in the improvement it brings to the understanding of the dynamics of electricity prices. Using various statistical tests, it provides a more in-depth analysis of the patterns in electricity



prices, indicating the presence of both stationary and explosive phases. This information can be useful to policymakers, energy market analysts, and investors in making informed decisions and developing strategies to mitigate some of the risks associated with explosive electricity price volatility during certain periods.

2. Literature review

Alessandrini and Petrella ([Lind](#)) studied the empirical explosive behavior of Italian electricity prices by using a comprehensive dataset and sophisticated econometric techniques. The authors captured periods of extreme price movements and characterized their underlying causes ([Hu & Oxley](#)). The research has revealed the importance of demand-supply imbalances, renewable energy, and regulatory changes in driving the explosive behavior of Italian electricity prices. The results emphasized the need for robust policy measures to mitigate price volatility and stabilize markets.

Fioretti and Otranto ([Khan & et al.](#)) used a regime-switching approach to identify speculative bubbles in the Italian electricity market. Analyzing different market regimes alongside relevant market fundamentals helped identify and delineate episodes of explosive price behavior in the electricity sector. The study emphasized the importance of distinguishing between price dynamics and fundamental causes, as well as speculative bubbles, for both market participants and policymakers ([Hui & Yue](#)). The results provided valuable insights into the mechanisms driving price bubbles and their potential consequences for market efficiency and consumer welfare. Grasso et al. ([Khan & et al.](#)) introduced a non-parametric approach to explosive dynamics in Italy's electricity prices. By applying distribution-free statistical tests, the authors demonstrated large price jumps and illustrated their explosive properties ([Phillips et al.](#)). Its significant aspect is that it considers the nonlinear and nonstationary aspects of electricity pricing dynamics, which pose challenges and make it difficult to precisely detect or control explosive behavior in this context. The findings provided stakeholders, regulatory bodies, and policymakers in the Italian electricity sector with sufficient knowledge.

The annual publication of the Italian Electricity Market Operator, or GME, featured an in-depth analysis of the Italian electricity market, focusing on the identification and characterization of electricity price volatility. It was a valuable source that discussed market trends, pricing mechanisms, and regulatory changes, thereby providing insight into extreme price swings and their causes. Therefore, it was the very resource that researchers and policymakers sought to understand and mitigate the volatile behavior of electricity prices in Italy.

The monitoring and analysis report issued by the Regulatory Authority for Energy, Networks, and Environment is a comprehensive document that evaluates the Italian electricity market, focusing on detecting and scrutinizing erratic fluctuations in electricity pricing ([Phillips & Yu](#)). The assessment examined market data, pricing trends, and behavioral patterns to identify and evaluate instances of significant price instability. The insights and results articulated in the report constituted a valuable resource for researchers and policymakers examining the volatile dynamics within the Italian electricity market.

3. Data Description and Research Methodology

This study uses spot electricity prices on a day-by-day basis from IPEX data, the Italian Power Exchange, for the period from January 1, 2020, to December 31, 2021, totaling 731 days. This interval overlaps the timeframe of the pandemic outbreak caused by the novel COVID-19. It investigates the price of electricity during this period in Italy.

This study employs three econometric techniques to achieve its objectives: the right-tailed ADF test, the SADF test, and the GSADF test. Many studies have used these techniques to detect bubbles in various time series ([Phillips et al., 2015](#)).

3.1 Right-tailed Augmented Dickey-Fuller (ADF) Test

To test for unit roots, several unit root tests have been proposed in econometrics; however, the ADF test is the most commonly used. ADF tests the null hypothesis that a unit root process is present in a time series sample ([Khan et al.](#)). The alternative hypothesis depends on the test used, but typically it is either stationarity or trend-stationarity. However, the alternate explosive hypothesis can also be used to identify explosive behavior in the time series under examination. Considering this alternative hypothesis, the following ADF model was used to develop a right-tailed ADF test, as reported in the literature.



can readily resolve this issue. This issue is being researched utilizing backward SADF statistics and a 95% confidence level.

4. Results and Discussion

Table 1 displays the descriptive statistics for electricity prices. The mean electricity price is 82.10. The maximum and minimum values of electricity prices are 437.94 and 10.65, respectively. The average deviation of each electricity price from its mean is 70.76. The skewness measurement indicates that electricity prices are positively skewed. Since the p-value of the Jarque-Bera test for electricity prices is less than 0.05, this indicates that electricity prices do not follow a normal distribution.

Table 1: Descriptive Analysis of Italian Electricity Prices

	Daily Avg Price
MEAN	82.10762
MEDIAN	55.51296
MAXIMUM	437.9409
MINIMUM	10.65931
STD. DEV.	70.76842
SKEWNESS	1.952036
KURTOSIS	ss 6.683521
JARQUE-BERA	877.5077
PROBABILITY	0.000000
OBSERVATIONS	731

Table 2 explains the result of the right-tailed ADF test for electricity prices. We conclude that electricity prices do not exhibit explosive behavior, as the price differences are statistically insignificant at the 10%, 5%, and 1% levels of significance.

Table 2: ADF Right Tail Test Results for Italian Electricity Prices

		t-Statistic	Prob.*
ADF		-0.931548	0.2160
Test critical values**:	99% level	0.732121	
	95% level	-0.071960	
	90% level	-0.443850	

Table 3 explains the result of the SADF test for electricity prices. It is noted that power prices are statistically significant (i.e., the null hypothesis of the unit root is rejected in favor of explosive behavior in the alternative hypothesis) as the SADF estimated value is higher than the critical value at the 1%, 5%, and 10% levels of significance. This suggests that the electricity price exhibits explosive behavior, which is identified at the end



of the 2nd quarter of 2021, and it has remained with random fluctuations till the end of the 3rd quarter of 2021, as shown in Figure 1. Similarly, explosive behavior was identified from the end of the 3rd quarter of 2021 to the end of the 4th quarter of 2021.

Table 3: SADF Right Tail Test Results for Italian Electricity Prices

		t-Statistic	Prob.*
SADF		5.872676	0.0000
Test critical values**:	99% level	2.109459	
	95% level	1.561664	
	90% level	1.261901	

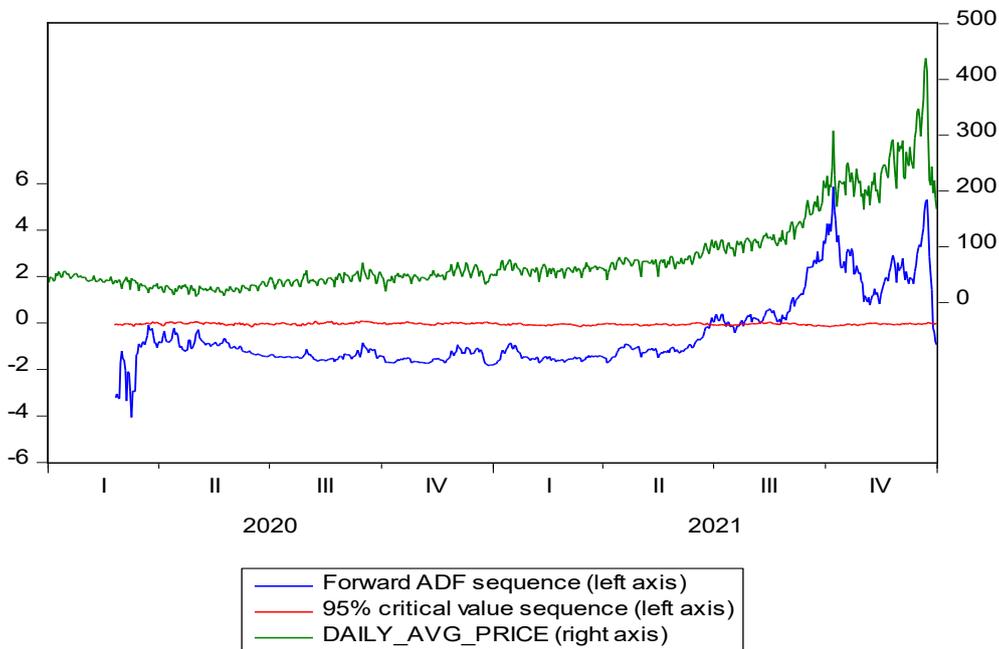


Figure 1: Bubbles Date Stamping for Italian Electricity Prices using SADF Test

Table 4 explains the results of the GSADF test for electricity prices. Electricity prices are shown to be statistically significant (i.e., the unit root null hypothesis is rejected in favor of the explosive behavior in the alternative hypothesis) since the GSADF estimated value is higher than the critical value at the 1%, 5%, and 10% level of significance. This indicates that electricity prices exhibit explosive behavior, which is detected at the end of the 2nd quarter of 2021, with random fluctuations persisting until the middle of the 3rd quarter of 2021. After that explosive behavior again occurred in the middle of the third quarter of 2021 and continued until the end of the fourth quarter of 2021, as shown in Figure 2.

Table 4: GSADF Right Tail Test Results for Italian Electricity Prices

		t-Statistic	Prob.*
GSADF		5.939799	0.0000
Test critical values**:	99% level	2.910760	



	95% level	2.296809
	90% level	2.082698

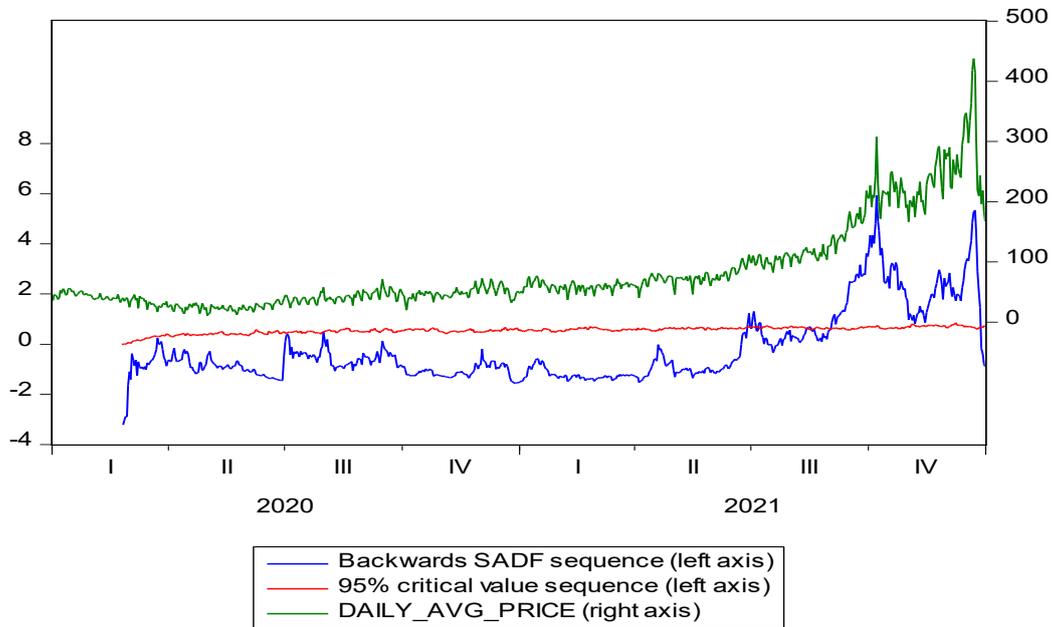


Figure 2: Bubbles Date Stamping for Italian Electricity Prices using the GSADF Test

5. Conclusion and Recommendation

Based on the results, we can draw the following conclusions regarding the behavior of electricity prices from January 2020 to December 2021, covering the period of the epidemic: The right-tail ADF test indicates that electricity prices do not exhibit explosive behavior during the period under consideration. But, as far as SADF and GSADF tests are concerned, they were consistent with explosive behavior. This explosive behavior is obtained at different intervals, for instance, from the end of the 2nd quarter of the year 2021 up to the last quarter of the 2nd quarter of the year 2021, and between the last quarter of the 3rd quarter of the year 2021 up to the end of the last quarter of the 4th quarter of the year 2021. To sum up, the ADF indicates that electricity prices do not exhibit a trend and thus do not display an explosive pattern; however, the tests performed by the SADF and GSADF suggest periods of pronounced movements in electricity prices. These intervals are characterized by random oscillations and can be studied to determine the factors that cause explosive behavior, as well as the effective behavioral pattern conducive to it.

Based on the analysis of electricity price dynamics, the following recommendations follow from the conclusions: Given recognized instances of volatile pricing, policymakers should explore introducing mechanisms to stabilize prices and mitigate the consequences for consumers. This may mean establishing price caps or ceilings during periods of significant price fluctuations, thereby protecting consumers from jarring, prohibitive price hikes.

A mix of energy sources must be implemented to mitigate exposure to price swings. Policymakers' priorities must include the development and integration of green energy systems, such as solar, wind, and hydropower. This will help shift reliance away from volatile fossil fuel prices and assist in establishing a more stable, environmentally responsible energy economy. Policies appear to place less emphasis on tightening supervision and control over the electricity market to identify and curb abusive practices that are likely to contribute to price volatility. This includes measures to promote competition, regulate pricing with a fair degree of transparency, and address anti-competitive practices. Effective market regulation enhances competition, reduces the potential for market abuse and manipulation, and reduces the volatility of electricity prices. Another way to manage



electricity demand on both the supply and demand sides to mitigate supply-and-demand mismatch outages during high-volatility periods is through load-shifting programs. These programs encourage consumers to adjust their energy use when prices are high or other specified conditions are met. Increased consumption tariffs encourage consumers to use electricity during off-peak periods, while decreased unit price tariffs reduce peak demand. Comparing contract agreements concluded by the seller and buyer regarding their scope and duration, long-term contracts can be seen as “shielding” agreements because they provide the seller or buyer with a better hedge against price fluctuations. This, along with the fact that long-term contracts become increasingly scarce as the market liberalizes, has led to greater use of spot-market pricing. The degree to which such instruments become effectively utilized hinges on market competitiveness and effective regulation of the market itself.

Promoting the need for energy consumers to take energy-saving measures and utilize energy-efficient technologies is a sure way to sustain low energy costs. There should also be enforcement of energy-saving practices through the imposition of energy supply tariffs that encourage consumers to reduce electricity waste. On the other hand, promoting energy-efficient technologies can go a long way in ensuring and stabilizing energy consumption at desired levels while keeping overall energy costs low for consumers.

Most importantly, because regional electricity markets exist, policymakers must collaborate with neighboring countries to efficiently manage price volatility. Furthermore, cross-border cooperation on best practices in line with regulations or alignment of energy policies might control prices across borders and enhance regional stability. These steps lead to the creation of a sustainable energy sector that aligns with economic growth and environmental protection policies.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent

Not applicable. This study uses publicly available, de-identified secondary data and does not involve human participants or personal information.

Competing interests

The authors declare no competing interests.

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