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Research article

Does US full vaccination against COVID-19 immunize correspondingly S&P500 index: Evidence from the NARDL approach

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A B S T R A C T

This study analyzes the impact of COVID-19 full vaccination shocks on the US stock market in the period January 14, 2021– August 20, 2021. Using the Nonlinear Autoregressive Distributed Lag model, we find that the positive and negative COVID-19 full vaccination growth shocks have a positive and symmetrical impact on the US stock market over the long run. Additionally, the short-run findings provide that the US stock market reacts negatively with delay to the positive and negative COVID-19 full vaccination growth shocks. The study findings provide good insights that COVID-19 full vaccination immunizes accordingly to the S&P 500 index in the long run. The study results indicate that the impact of positive and negative COVID-19 full vaccination growth shocks on the stock market in the short run differs from that in the long run. This research bears important implications: governments should implement preventive measures with vaccination to recover the stock market. Policy makers ought to urge adopting policy measures to reduce panic and boost investor confidence during economic and health crises.

1. Introduction

The last decade has seen the occurrence of many crises including the recent COVID-19 pandemic. This unprecedented health crisis has hit hard: an exponential increase in the number of contaminations and deaths worldwide e.g. Ref. [31] massive lockdowns, panic, fear, and extensive damage e.g. Ref. [15]. Since the start of 2020, the United States has become the first focus of the COVID-19 pandemic in terms of the number of infected cases (34,482,672) and deaths (619,152) ahead of India, Brazil, and France.[1]

Beyond the health tragedy, the COVID-19 pandemic sow both uncertainty and investment risk to rise sharply in international financial markets which have fallen one after the other e.g. Refs. [109,114]. Similar to its rapid spread among individuals, the COVID-19 disease ended up contaminating the atmosphere of trading rooms where the first symptom of the crisis was detected on February 19, 2020,[2] by the decline of the S&P500 index by more than 20% from its peak.

A new Black Monday was marked on March 9, 2020 causing the New York Stock Exchange to shut down completely after hitting an all-time lower bound of 7%.[3] This health crisis triggered the fastest stock market crash in the United States since the 2007-2009.[4]

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[1] https://www.worldometers.info/coronavirus/country/us.
[2] https://www.statista.com/statistics.
[3] https://www.thebalance.com/fundamentals-of-the-2020-market-crash-4799950.
[4] https://www.thebalance.com/what-is-black-monday-in-1987-1929-and-2015-3305818.

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During the first half of 2020,[5] The COVID-19 pandemic ended up affecting other stock exchanges around the world like the CAC 40, the FTSE 100, the Dax, the Japanese Nikkei, and the Shanghai index dramatically fell respectively by 17%, 13%, 7%, 5%, and 4%. The economic situation deteriorated further on April 20, 2020, with the collapse of oil prices.

Faced with the seriousness of the disease, its rapid spread and its harmful consequences for the global economy, governments are looking for solutions not only to save lives but also to restore the stability of financial markets. In 2021, principal headlines focus more on the vaccine's application against COVID-19. Working as fast as possible, scientists around the world are collaborating and innovating to provide vaccines. According to economists, the economic recovery is closely linked to the pandemic spread, which will depend on the evolution and effectiveness of vaccine inventions.

On November 9, 2020, the S&P500 and Dow Jones indices enthusiastically welcomed news of Pfizer/BioNTech vaccine efficacy reaching 90%[6] and setting new all-time intraday highs at 3,600 and 29,933.83 points respectively. A few days later, the logic company announced its vaccine with an efficacy of around 94.5%. This news led to a spectacular session market opening and a rebound of the New York Stock Exchange. The development of vaccines against COVID-19 has triggered an exceptional wave of euphoria in the stock markets and renewed hope for investors. Also, oil reacted positively to the news relating to the development of vaccines against COVID-19 and jumped by 8%[7] unlike gold which fell by 5%.[8]

Through data published by the World Health Organization (WHO), a drop in the number of new cases and deaths is well remarkable following the taking of vaccination against COVID-19. As well, on September 9, 2021, the Reuters vaccine tracker reported that the number of vaccine doses administered worldwide is 5,587,630,000 against 222,915,000 new infections and 4,776,000 deaths; in addition, the National Bank of Canada[9] illustrated the slowdown in the spread of COVID-19 pandemic in some countries. Additionally, from January 10, 2021 to June 28, 2021, the World in data website[10] reported that the new COVID-19 confirmed cases (per million of the population) decreased from 730.177.57 to 377.005.22 (a decline about -48.36%) and the daily COVID-19 deaths (per million of the population) fell from 13.247.57 to 9.887.57 (a decrease about 25.36%).

Interestingly, vaccinations showing effectiveness in reducing contamination cases and immunization against COVID-19, have also succeeded in improving the investor's sentiment. Governments imposed a second dose of vaccines with the aim that full vaccination will further strengthen individual immunization against COVID-19 and allow the relaxation of protection restrictions. In Refs. [65,73], the authors affirm the effectiveness of COVID-19 full vaccination and confirm that the immunity of those who took two doses is better than those who took only one. In Refs. [87,96,101,104] the authors admit that vaccination is very important at all ages. Their finding is contradictory with Refs. [25,43].

With the growing number of fully vaccinated, economic actors will feel more secure and plan positively. In fact, governments are adopting mass vaccinations not only to reduce the negative consequences of the COVID-19 pandemic and limit the burdens on health systems, but also to improve economic activity and give hope for stock market stability e.g. Refs. [21,71]. The acceleration of the COVID-19 full vaccination program in the USA and the companies reopening have reduced health stress, increased investor confidence and a favorable atmosphere is beginning to emerge in the financial markets. With sufficient availability of vaccine doses, mass vaccination programs save lives and offer hope of restoring the stock market.

In times of instability and uncertainty, investor behavior as well as the reaction of stock markets to economic news is difficult to predict. However, how COVID-19 vaccination affects stock markets does not yet seem to be clearly defined. In this logic, a reflection is necessary, and a question arises concerning the capacity of the COVID-19 full vaccination used to develop human immunity against the COVID-19 pandemic, to succeed in immunizing the American stock market also against the COVID -19 crisis. Our study sheds light on this issue with the expectation that the COVID-19 full vaccination growth should stimulate positive investor sentiment and impact positively on the US stock market.

The objective of this framework is to investigate at how positive and negative COVID-19 full vaccination growth shocks affect the stock market in the United States in the short and long run. This study aims to provide evidence for the dynamic relationship between COVID-19 full vaccination growth and the S&P500 index in the short and long run.

The motivation of this research is to provide answers to the following questions: Does the stock market reaction differs according to COVID-19 full vaccination growth shocks either positive or negative? Does the increase in the COVID-19 full vaccination growth offers immunity to the US stock market? Does the impact of positive or negative shocks of COVID-19 full vaccination growth in the stock market have the same in the short run as in the long run?

The paper contributes to the existing literature in four dimensions. Firstly, this study investigates whether scientific inventions against infectious diseases have impact on stock markets. Secondly, noting the fact that studies exploring the stock market behavior during crises are very limited, given the rarity of such events. Given that the COVID-19 pandemic considered as the unique special case of a double health and economic crisis, we contribute to previous studies by examining the reaction of the S&P500 index to the COVID-19 full vaccination growth shocks in presence of other macroeconomic factors shock factors. Thirdly, the number of studies on the relationship between vaccination and the stock market is limited. Thus, we contribute through this study to enrich the research linking the two fields of finance and medicine. Fourthly, no study considered either the impact of the decline as well as the raise of

[5] https://www.investing.com/indices.

[6] https://www.pfizer.com/news/press-release/press-release-detail/pfizer-and-biontech-announce-vaccine-candidate-against.

[7] https://www.reuters.com/article/global-oil-int-idUSKBN27P0CM.

[8] https://www.businesslive.co.za/bd/markets/2020-11-09-gold-falls-nearly-5-on-COVID-19-vaccine-euphoria/.

[9] https://ourworldindata.org/COVID-vaccinations.

[10] https://graphics.reuters.com/world-coronavirus-tracker-and-maps/.

vaccination on the stock market, nor verified whether the short-run impact persists in the long run. This is a research gap that we fill through this work.

To address the study objective and fill the research gap, this paper examines how S&P500 index reacts to the COVID-19 full vaccination growth shocks while controlling the impact of oil, gold and economic policy uncertainty shocks. This research applies the Nonlinear Autoregressive Distributed Lag analysis on daily time series data extending from 14 January 2021 to 20 August 2021.

We use the NARDL approach which takes into consideration the temporal dynamics (the delay time (lag)) in the explanation of our variables and improves the predictions and the effectiveness of our results. In fact, the available data on vaccination may have an impact the same day and / or will have delayed fallout a few days later. Also, the choice of the NARDL approach is explained by the objective of analyzing how vaccination affects the S&P500 index in the short and long run. This method makes it possible to determine the positive and negative shocks of the regression using asymmetric dynamic multipliers.

We chose the S&P500 stock market index for various reasons. First, it is considered a common benchmark for global economic health. Second, the United States has long been registered at the top of the countries most affected by COVID-19, according to the reports of the BBC news and Johns Hopkins University.[11] Third, the United States belongs to the major countries that produced the first vaccines. Fourth, the USA is the second country after China that has vaccinated the most people since the start of the campaigns.

Some remarkable results can be seeming from this study: the impact of the US full vaccination growth shocks on the S&P500 index is depicted by a change from an asymmetric effect in the short run to a symmetric impact in the long run. The study findings provide good insights. First, we discover that the US full vaccination against COVID-19 immunizes correspondingly S&P500 index in the long run. Second, the US stock market reacts similarly to positive and negative COVID-19 full vaccination growth shocks. The third bright spot of these findings is that the impact of positive or negative COVID-19 full vaccination growth shocks on the stock market in the short run differs from that in the long run. This research stands for important implications: governments should adopt policy measures to reduce panic and boost investor confidence during economic and health crises and implement preventive measures with vaccination to recover the stock market.

To our knowledge, this is the first study on this topic to apply the NARDL model to discover the effect of positive and negative shocks of COVID-19 full vaccination growth rate on the US stock market in the short- and long-run. Compared to the existing literature, the novelty of this paper is that is the most recent and the first to verify the role of vaccination in the immunization of the US stock market in the short run and long run and secondly to investigate the dynamic effects of increasing and decreasing of full vaccination growth rate.

Hence, this research provides answers to the following questions: Does the stock market reaction differs according to COVID-19 full vaccination growth shocks either positive or negative? Does the increase in the COVID-19 full vaccination growth offer immunity to the US stock market? The impact of positive or negative shocks of COVID-19 full vaccination growth in the stock market is the same in the short run as in the long run?

The structure of the remaining part of the paper is arranged as follows; Section 2 is literature and theoretical background, Section 3 shows data collection and research methods. Section 4 presents empirical findings and discussions. Finally, the study offers the conclusions and some policy implications.

2. Literature review and theoretical background

Based on the Arbitrage Pricing Theory (APT), several macroeconomic factors can influence the financial market and define its risk and return e.g. Ref. [12]. In Ref. [67,74] the authors argued that stock market updates everything according to information, according to the efficient market hypothesis (EMH) or theory. In Ref. [72,105] the authors describe the (EMH) by the fact that the stock price reflects all available information, which makes it completely impossible to obtain a constant alpha or excess returns. According to [72], many previous researches have shown that information and many non-stock news and events stimulate stock market returns e.g. Refs. [35,75]. Based on the efficient market hypothesis, the literature presents many studies examining the effect of different types of information on the stock market performance. Among the information covered by research and having a significant impact on stock market price include: corporate events e.g. Ref. [63], political events, health events e.g. Ref. [36], new brand or product announcements e.g. Ref. [21], general economic events, job layoffs and cutbacks e.g. Ref. [58].

2.1. Stock market before COVID-19 pandemic

Before the COVID-19 pandemic, there was a wave of research dealing with the relationship between stock market performance and macroeconomic variables such as oil and gold prices, Economic policy and uncertainty in many contexts studies e.g. Ref. [12]. However, these authors presume that the stock market and oil price are linked to each other and consider the empirical findings regarding the association between the two variables are mixed. Some studies found a negative relationship between the oil price and the stock market e.g. Refs. [13,68,113]. On the other hand, other researchers confirmed the existence of a positive linkage between the variables e.g. Refs. [46,22,39,70]. While Ref. [44] found no relationship at all. The authors in Ref. [42] believed that gold is a real asset with lower risk than other assets. They supposed that some investors favor the “flight to quality” way by removing their riskier money poured into the stock market into a safer asset (gold). Therefore, many studies tested the linkage between gold and the stock market and found a negative relationship Refs. [1,5,9,10,89], while others demonstrated a positive association between them

[11] https://coronavirus.jhu.edu/map.html.

e.g. Refs. [6,11]. However, Ref. [99] did not find any relationship. In Ref. [103] the authors assumed that the impact of economic policy and uncertainty (EPU) defines stock market performance by observing in previous literature. The authors in [45,80] consider economic policy and uncertainty (EPU) as the main determinant of the game rules of economic agents by the fact that it stimulates decisions, cause the increase of financing and production costs and increase risk in financial markets by limiting public authorities market protections. Over study periods between 2000 and 2017, some researchers found a negative relationship between economic policy and uncertainty (EPU) and stock market e.g. Refs. [23,60,62], while others confirmed the existence of a positive linkage between the variables e.g. Ref. [32]. According to Ref. [12], the continuing discrepancy between the results of previous studies states that the relationship between macroeconomic factors and the stock market is still inconsistent and at discuss.

Several researchers have shown the relationship between macroeconomic variables and the stock market before COVID-19 pandemic, on the other hand, after COVID-19 pandemic, some researchers have studied the relationship between the COVID-19 vaccination and the stock market, as presented in Table 1.

2.2. Stock market during COVID-19 pandemic and before the vaccination process

By causing an unprecedented health and economic crisis between December 2019 and March 2021, the COVID-19 pandemic caused the most historic stock market crash of March 2020 and disrupted the financial and economic system. During the COVID-19 crisis, a great body of research has prompted reflection on the impact of the COVID-19 pandemic indicators on the performance of global stock markets e.g. Refs. [17,93]. The first wave of studies addressed the effect of confirmed cases and deaths of COVID-19 on stock market performance. Over the period January 22, 2020 to April 17, 2020, Ref. [14] found that stock market returns of 64 countries reacted negatively to the growth of COVID-19 confirmed cases earlier than to the growth in COVID-19 deaths, by using a panel data analysis. Similarly, in Ref. [7] concluded that the daily confirmed COVID-19 cases and the total number of COVID-19 deaths have, from January 10, 2020 to March 16, 2020, significant negative impact on the stock returns of the Chinese stock market, by a panel data analysis. Likewise, in examining the stock markets in five regional epicenters, in Ref. [77] found that the daily total cases of COVID-19 affect stock market index prices in Spain, Italy, United Kingdom and United States. Also, based on an ordinary least squares (OLS) regression, in Ref. [8] concluded that the impact of announcements of new COVID-19 cases and the death rate stimulate the volatility of the S&P 500 index. Similarly, in Ref. [78] proved that the number of reported COVID-19 deaths in Italy and France had a negative impact on the US stock market (measured by Dow Jones and S&P500 indices) using the Garch model. The second wave of studies lectured on the effect of the uncertainty and fear triggered by COVID-19 on stock market performance. Using an event study method, the authors in Ref. [61] confirmed that the COVID-19 crisis quickly affected the 21 major stock market indices of the most affected countries and that investors' sentiment of fear was the feature for the rapid transmission of the impact of the pandemic on the various stock markets. As well, using the panel data analysis, Ref. [88] discovered that 24 emerging countries' stock markets are more vulnerable to the uncertainty and fear index generated by the COVID-19 pandemic contrarily to developed markets. Furthermore, in Ref. [79] the authors stated that anxiety caused by the COVID-19 pandemic affects the stock market volatility in Europe, Asia, the United States and Australia, through a panel data analysis. Other studies have focused on verifying the effect of certain government interventions to limit the COVID-19 pandemic. For example, in Ref. [19] confirmed that government restrictions on business activity and international trade are the reason for the strong negative reaction of US shares during the COVID-19 pandemic. In addition, in Ref. [86] indicated that government interventions supposed effective and related to COVID-19 (containment, shutdown policies and economic stimuli) have supported the stock market in 67 countries, from January to April 2020. While some studies in the literature have considered the effects of COVID-19 related news on the stock market. By employing the Dow Jones index and its 23 sector sub-indices over the period from January 1, 2020 to April 30, 2020. Ref. [47] demonstrated that the panic generated by news related to COVID-19 pandemic increased stock market volatility. In addition, the author in Ref. [28] examined the stock market's reaction to coronavirus news in the six most affected countries by the COVID-19 pandemic. The author found that stock market returns depend on information related to COVID-19 (fake news and media coverage), by using a panel quantile regression model. Numerous studies have been conducted to reveal similarities and differences between countries through examining the effects of COVID-19 e.g. Refs. [54,71,97]. Moreover, in Ref. [9] the authors specified that in the United States, United Kingdom, Germany and South Korea, the stock market volatility average was higher during the pandemic phase than during the epidemic stage. The authors showed that the Europe Union (EU) regional index volatility was higher during the United States (US) phase than during the phase when the EU recorded the highest number of fatalities. Nonetheless, they revealed that the stock market returns in China declined slightly during both phases of the COVID-19 pandemic. As well, in Ref. [111], the authors showed that the stock market risk of the first top 10 countries in the list of confirmed COVID-19 cases on March 27, 2020 increased following the pandemic. The response of each stock market varies and depends on the severity of the outbreak in each country. Alternatively, in Ref. [31] the authors mentioned that the US and Chinese stock markets are volatile during the rapid spread of COVID-19 in the United States. The results indicated that the pandemic is negatively affecting financial markets and in particular US stock market during the first and second waves of the epidemic. Also, in e.g. Ref. [106] the author focused on the dynamic responses of the Canadian and American stock markets to the cases and uncertainty engendered by the COVID-19 pandemic. He found that uncertainty and the increase in the number of COVID-19 cases had a significant negative impact on the US stock market during the pandemic. On the other hand, some research has revealed the existence of a positive relationship between COVID-19 pandemic and the stock market price of companies in the health, food and technology sectors e.g. Ref. [64]. The literature indicates that other studies have not indicated a clear relationship e.g. Ref. [26].

During the COVID-19 crisis, the link between the stock market and macroeconomic factors has been also extensively studied, but the results found mixed e.g. Ref. [12]. Since the outbreak of the COVID-19 crisis, the oil price has been negatively influenced by

Table 1
Review of selected studies on the relationship between stock market and COVID-19 vaccination.

Authors	Period	Method	Variables	Countries	Main results
Khalfaoui et al. [55]	December 20, 2020–April 9, 2021	Multiple wavelet coherence	Stock market return, Infection rate, Vaccination rate, Case Fatality Ratio	USA	the S&P 500 index is positively affected by COVID-19 vaccination
Rouatbi et al. [86]	from January 1, 2020 to April 30, 2021	Pooled OLS	Stock return volatility, daily vaccination, Δ Infections to Cases, ΔDeaths to Cases,	66 countries	The impact of vaccination impact is stronger on developed markets than in emerging markets.
Demir et al. [38]	from January 1, 2020 to April 30, 2021	Pooled OLS, REM	Stock return volatility, daily vaccination, Δ Infections to Cases, ΔDeaths to Cases	58 countries	Vaccination reduces energy stock volatility
Cong Nguyen To et al. [69]	From March 11 to October 29. 2021	Asymmetrical GJR GARCH	Stock return volatility, Vaccine initiation rate, Daily relative change of COVID-19 total cases and deaths	34 countries developed and developing countries	the rate of COVID-19 vaccine initiation has a positive effect on international stock markets
Ho et al. [50]	February 25, 2021 March 17, 2021 May 07, 2021 June 01, 2021	Event study methodology	Cumulative abnormal returns (CARs), return on assets, tangible assets ratio, financial leverage, Age of firm, and Size of firm	China	The COVID-19 vaccine announcement has a positive effect on stock price
Chan et al. [30]	January 2, 2020, to April 30, 2021	Panel data regression	Daily abnormal return, Daily growth rate of COVID-19- confirmed cases, daily growth rate of COVID-19-related death cases, Bull-bear spread, CBOE VIX	23 developed economies and 27 emerging economies	The average global stock market abnormal return reacted positively to the first day of the trials
Oanh [76]	between March 11, 2020 and October 29, 2021	the panel data vector autoregression (PVAR) model	Stock market return Vaccination rate Infection rate Case Fatality Ratio	77 countries, including 37 developed and 40 developing countries	COVID-19 vaccination has a positive effect on stock markets in developing countries and a negative impact on developed countries.
Badmus and Ojelade [17]	from 4th April 2019 to 7th May 2021	regression with heteroscedasticity and wavelet consistency analysis	stock market performance two proxies of vaccination are adopted: indicator variable and the vaccination index.	11 African countries	Stock markets were positively affected by vaccination against COVID-19
Unal et al [97]	between 31.12.2020 and 28.09.2021	Test of difference	COVID-19 vaccination rates and stock index performance	49 countries from the MSCI	Stock markets in countries where vaccination is applied quickly and reached vaccination rates of 10% and 50% of the population perform better and experience lower volatility
Herlina et al [49]	from March 13th, 2021, until July 7th, 2021	panel regression model	daily return of stocks, vaccines growth and cases growth	six ASEAN countries	The daily increase in vaccination negatively affects stock market performance.
Abdullah et al. [2]	from February 28, 2021 to August 31, 2021	Ordinary Least Square (OLS) regression	number of confirmed cases of COVID -19, patients cured of COVID -19, COVID -19 deaths and fully vaccinated people the composite index of Kuala Lumpur	Malaysia	The Malaysian stock market performance was affected positively by the number of fully vaccinated people.
Mishra et al. [67]	from January 22, 2020 to April 30, 2021	ARDL approach	Dow Jones Industrial Average, Total confirmed cases, Total confirmed deaths, Total vaccination, Stringency index	USA	vaccination had a positive and effect on the Dow Jones index
Behera et al. [18]	February 1, 2021, to July 30, 2021	Exploratory Data Analysis, Machine Learning process, Linear Regression, Support Vector Regression, Random Forest Regression, and KNN Regression model	total vaccinated people, The closing price of the stock market, vaccination and death rate	India	vaccination had a positive impact on the Indian stock market performance

Author's own compilation.

protective government measures (social distancing, workplace closings, lockdown, suspension of air travel and transport….). Many studies have found a negative relationship between oil prices and stock markets during the COVID-19 crisis e.g. Refs. [33,75], while a positive relationship between the two factors has been found by Ref. [83]. However, Ref. [57]) indicated there was no relationship. Through the COVID-19 crisis, the gold price reacted positively to the pandemic e.g. Refs. [15,56]. In Ref. [91,92] the authors declared that gold price is negatively and weakly correlated to stock market indices during the COVID-19 crises. The authors in Ref. [112] confirmed the role of gold as a safe haven asset during the different phases of the COVID-19 crisis and especially from March 17, 2020 to April 24, 2020. However, in Ref. [59], the authors confirmed that gold returns influenced the variation of the S&P 500 index and vice versa. Authors in Ref. [112] suggested the existence of connectivity between stock market and the uncertainty prompted by the COVID-19 pandemic. Thereby, the authors in Ref. [108] confirmed that the S&P 500 index depends on the economic policy uncertainty index (EPU). In addition, authors in Ref. [92] indicate that the spread of COVID-19 has led to an increase in the economic policy uncertainty index that generated the weakening of the US stock market.

2.3. Stock market during COVID-19 vaccination process

From the end of 2020 with the first declarations concerning the development of vaccines against COVID-19, some researchers have focused on predicting the reaction of financial markets to the development and clinical trials of these vaccines. Indeed, it seems exceptional and rare before finding research joining the two fields: medicine and finance. Pioneering studies in this area include the research in Ref. [51] which investigated the effect of the development of new cancer drugs on the stock market returns of pharmaceutical companies. In related studies, e.g. Ref. [85,52,29] authors analyzed the impact of successful clinical drug trials on stock market returns. On the other hand, we recall that the author in Ref. [20] examined the stock market reaction to the approval of new drugs by the US FDA. The author found that stock prices of pharmaceutical companies jumped following the approval of new drugs by the US FDA. After COVID-19 vaccination, Authors in Ref. [3] expected the restoration of investor confidence and stock market stability. In Ref. [41,48], authors considered vaccine development as a “game changer” for the recovery of social and economic conditions and believe that positive investor sentiment toward the vaccine program will help boost stock market performance. In the period after the vaccine of COVID-19 pandemic, a new and emerging research orientation has recently developed and drawn the attention of academics to investigate the impact of the development of vaccines on the stock market. The practice of vaccination against COVID-19 has recently been the subject of academic studies, but it remains limited. By applying the multiple wavelet coherence approach, authors in Ref. [55] examined the association between the number of COVID-19 infections, deaths, vaccinations and US stock index performance during the period between December 20, 2020 and April 9, 2021. The results indicated that infection rate, case fatality rate and vaccination against COVID-19 impact positively the S&P 500 return. Using pooled ordinary least squares (OLS), fixed effects and random effects estimator methods, authors in Ref. [89] studied the impact of news of mass COVID-19 vaccination programs on stock market volatility of 66 countries from January 1, 2020 to April 30, 2021. The results stated that the role of vaccinations is relatively stronger in developed markets than in emerging markets. The authors supposed that the early development of mass vaccinations helped stabilize the stock market by observing the decrease in stock market volatility in certain countries. Authors in Ref. [69] found that the rate of COVID-19 vaccine initiation has a positive effect on international stock markets. This significant effect was stronger for stock markets in developed countries and with higher vaccination rates. Studying stock market data from 58 countries from January 2020 to April 2021, authors in Ref. [38] concluded that vaccination contributes to reducing the volatility of energy stocks, especially in developed countries markets rather than emerging markets. The author in Ref. [72] analyzed the reaction of the five major global stock indices (Dow Jones, Shanghai, S&P, FTSE and EURONEXT) to the arrival of the COVID-19 vaccine. His research focused on data on stock price performance for seven months before the vaccine arrived and seven months during the period when vaccinations were available. The results of the differential analysis used showed that stock prices increase more when the vaccine arrives than before it arrived. When the vaccine arrives, the increases in the share prices of the various indices vary between 7% and 20%. The authors in Ref. [50,37] analyzed Chinese stock market responses to COVID-19 announcements vaccine approvals by sector. The results revealed that mainly, the stock prices of companies belonging to the sectors of manufacturing, wholesale, retail and information technology sectors rose following vaccine announcements. In addition, the authors found that stock prices of older and smaller companies responded more positively to COVID-19 announcements vaccine approvals relative to others. Moreover, authors in Ref. [30] found that stock markets reacted positively during the different phases of clinical trials of vaccines against COVID-19. The first day of testing leads to a significant increase in average abnormal stock return at 8.08. The positive increase in average abnormal stock performance is more pronounced from the start of phase III trials and especially in the case of candidate vaccines developed by the United States and China. The author in Ref. [76] examined the impact of COVID-19 vaccination on the stock markets of 77 countries between March 11, 2020 and October 29, 2021. By using the panel data vector autoregression (PVAR) model, the author found that COVID-19 vaccination has a positive effect on stock markets in developing countries and a negative impact on developed countries. Study results indicated that the COVID-19 vaccination explains the stock market return to developing countries (at 0.00026%) more than to developed countries (only 0.00022%). Author in Ref. [17] analyze the impact of vaccination against COVID-19 on the stock market performance of 11 African countries. This study applied both consistent regression with heteroscedasticity and wavelet consistency analysis. To measure vaccination against COVID-19, two proxies are adopted: the indicator variable and the vaccination index. The results illustrated that stock markets were positively affected by vaccination against COVID-19 using the dummy variable in Botswana, Côte d’Ivoire and Zambia and by adopting the vaccination index for Kenya, Uganda and Zambia. Authors in Ref. [97] examined the relationship between COVID-19 vaccination rates and stock index performance. In this study, indices from 49 MSCI countries were used and grouped according to when they recorded the following vaccination rates: 10%, 50% and 75%. The authors began by verifying the existence of differences between the stock market returns of countries by group according to their performance in terms of vaccination. The results indicated that stock markets in countries where vaccination is applied quickly and reached vaccination rates of 10% and 50% of the population performs better and experience lower volatility. On the other hand, the relationship between reaching the vaccination level of 75% and stock market performance turns out to be statistically insignificant. Using a panel regression model, Author in Ref. [49] explored the impact of vaccination on the stock market returns of six ASEAN countries. The authors mainly used three variables: the daily return of stocks, the growth of vaccines, and the growth of cases. The results seem contradictory and show that the daily increase

Table 2
Variable description and source of data.

Variable	Symbol	Description and measurement	Data source
US stock market	S&P500	S&P500 index price. Refs. [2,18]	www.investing.com
COVID-19 full vaccination growth rate	VACR	Author's own compilation, VACR is given by (1)	the World Health Organization (WHO) www.COVIDax.live https://coronavirus.jhu.edu/map.html https://www.cdc.gov/coronavirus/2019-ncov/index.html Refs. [27,53].
	OILWTI	The West Texas Intermediate (WTI) crude oil price. Ref. [102]	the US Energy Information Administration https://www.eia.gov/
Macroeconomic Fundamentals	GOLD	The daily gold price. Refs. [9,66,107]	www.investing.com
	EPU	Economic Policy Uncertainty index. Refs. [12,19,103]	the Federal Reserve Economic Data https://fred.stlouisfed.org/

Author's own compilation.

in vaccination negatively affects stock market performance. Using Ordinary Least Square (OLS) regression, over the period from February 28, 2021 to August 31, 2021, Author in Ref. [2] studied the impact of number of confirmed cases of COVID -19, patients cured of COVID -19, COVID -19 deaths and fully vaccinated people on the composite index of Kuala Lumpur. The results showed that Malaysian stock market performance was affected negatively by confirmed COVID-19 cases and positively by the number of fully vaccinated people. Ref. [67] examined the long-term and short-term impact of infected cases, COVID-19 deaths, vaccinations and the stringency index on the US stock market from January 22, 2020 to April 30, 2021. The results of the ARDL approach demonstrate that in the long term, confirmed cases have a significantly negative impact on the Dow Jones index while vaccinations have a positive and significant effect. Using the Machine Learning process, Linear Regression, Support Vector Regression, Random Forest Regression, and KNN Regression model, authors in Ref. [18] showed that the vaccination led to a reduction in the mortality rate and had a positive impact on the Indian stock market performance. Table 1 recaps studies investigated the impact of COVID-19 vaccination on the stock market.

Using different methods, pioneering research demonstrated the positive impact of vaccination on the stock market. However, no study considered neither the impact of the decline as well as the raise of vaccination on stock market performance, nor verified whether the short-run impact persists in the long run. This is a research gap that we fill through this work.

Therefore, this study has three important contributions as follows. First, the number of studies on the relationship between vaccination and the stock market is limited. Second, the study was conducted with the aim of looking at the short-run and long-run effects of full vaccination on the stock market. Third, no previous study has taken into account the impact of the decrease in the vaccination rate as its increase on the stock market. The results revealed that positive and negative shocks of the full vaccination growth rate have varied short and long-run effects on the stock market.

Finally, to our knowledge, this is the first study on this topic to apply the NARDL model to discover the effect of positive and negative shocks of the full vaccination growth rate on the US stock market in the short and the long run. Compared to the existing literature, the novelty of this paper is offered by the fact that it proposes primarily to verify the role of vaccination in the immunization of the US stock market in the short-term and long-term and secondly to investigate the dynamic effects of increasing and decreasing of full vaccination growth rate.

3. Data and methodology

A growing body of literature analyses the relationship between the stock market and the vaccination against COVID-19 using various econometric models (Pooled OLS in Ref. [86] and in Ref. [38]; Multiple wavelet coherence in Ref. [55]; Asymmetrical GJR GARCH in Ref. [69]). In the present research paper, the asymmetric ARDL model introduced in Ref. [94] will be used to achieve the objective proposed in the present paper in terms of obtaining consistent results explaining the impact of full vaccination against COVID-19 growth rate on S&P500 as well as analyzing the short and long run interconnection between the full vaccination against COVID-19 growth rate, crude oil and gold price shocks and the American stock market S&P500 during the pandemic crisis.

In this study, we use daily data on the S&P500 stock index price and the number of fully vaccinated in the United States. The study period is from January 14, 2021 (the date when WHO declares Americans are receiving the second dose of vaccination and data are available) to August 20, 2021 (the date before the appearance of new variants of the coronavirus) (143 observations after eliminating the missing values). According to the literature review mentioned above, several macroeconomic factors may affect the S&P500 index price during this pandemic crisis. In the current study we investigate some of these factors such as oil price, gold price, and economic policy uncertainty.

3.1. Data

Using the data set related to the number of daily fully vaccinated against COVID-19 in the United States, we calculate the COVID-19 full vaccination growth rate against COVID-19 (VACR) as follows:

$$VACR = \frac{\text{number of fully vaccinated } (t) - \text{number of fully vaccinated } (t-1)}{\text{number of fully vaccinated } (t)} \tag{1}$$

Table 3
Descriptive statistics.

	EPU	GOLD	OILWTI	S&P500	VACR
Mean	141.8090	1797.593	64.78291	4127.745	0.031971
Median	128.9400	1797.000	64.88000	4170.160	0.010685
Maximum	405.1000	1910.500	75.35000	4464.840	0.268415
Minimum	57.43000	1678.000	52.16000	3714.240	0.000853
Std. Dev.	60.38686	54.59373	6.003240	205.2102	0.052903
Skewness	1.362012	0.156891	−0.210922	−0.155104	2.706076
Kurtosis	5.289454	2.320794	2.351669	1.841816	10.43705
Jarque-Bera	79.66452	3.522200	3.764510	9.045013	532.2820
Probability	0.000000	0.171856	0.152269	0.010862	0.000000

Source: Data statistics are over the period of January 14, 2021 - August 20, 2021.

Table 4
Correlations coefficient matrix.

	EPU	GOLD	OILWTI	S&P500	VACR
EPU	1	−0.0896499	−0.3403357	−0.3606373	−0.3674433
GOLD	−0.0896499	1	0.05315110	0.15993691	0.22603591
OILWTI	−0.3403357	0.05315110	1	0.81508844	0.86729480
S&P500	−0.3606373	0.15993691	0.81508844	1	0.95981030
VACR	−0.3674433	0.22603591	0.86729480	0.95981030	1

Source: The authors' computations from EViews 12.

The research model variables are defined in Table 2.

An essential step to perform before scrutinizing the asymmetric relationship between dependent and explanatory variables is to describe the characteristics of variables and their correlation.

Table 3 presents descriptive statistics of variables in the present study. We note that the USA touched, during the studied period, a maximum growth rate in terms of full vaccination (around 26%) with a daily average growth of 3.19%. These statistical results indicate the great commitment of the US to immunize their citizens who have shown a broad demand for mass vaccination against COVID-19. The S&P500 index price and the Economic Policy Uncertainty index are the most volatile by standard deviation value over the studied period. This result is consistent with the findings of authors in Refs. [92,103]. We notice that the S&P500 index dispersion value (205.2102) is close to that found by Ref. [95], (221.3987) from 22 January 2020 to 17 May 2020. The Economic Policy Uncertainty index reaches a high value (405.1000) with a standard deviation of 60.38686 indicating that during the studied period uncertainty and economic panic persist due to the COVID-19 pandemic. However, these values are lower than those of the study by Ref, [15] (first half of 2020), when the pandemic spread was more aggressive with the absence of vaccines. The high dispersion of the EPU explains that investors are uncertain about investing in the United States as many industrial unit closures and the slowdown in the recovery of economic activity during the start of the COVID-19 vaccination phase.

Further, we observe that the average of oil and gold prices are 64.78291$ and 1797.593$ respectively. These values seem to have increased compared to the year 2020 according to Ref. [15]. We notice that Gold has a higher dispersion value compared to OIL, in accordance with the study in Ref. [95]. The Jarque-Bera test shows that OILWTI and GOLD prices are normally distributed ($p \geq 0.05$) but VACR, EPU and S&P 500 are not. To solve the non-normality problem, we apply the NARDL model.

Table 4 illustrates the results of the Pearson correlation coefficient in a matrix format. The studied variables are mostly positively correlated with each other except EPU, which is negatively correlated with all dependent and independent variables. The correlation coefficient between S&P 500 and VACR is 0.95981030 indicating a very strong positive correlation between both variables which means that when one variable changes, the other variable changes in the same direction. Similarly, high correlation is present between OILWTI and S&P 500 (0.81508844) and VACR with a coefficient of (0.86729480). We notice that GOLD is positively correlated with S&P500 (0.15993691) and VACR (0.22603591).

3.2. Econometric methods

Over the last several years, the financial literacy has utilized different methods such as ordinary least squares (OLS), quantile regression (QR) and support vector regression (SVR) models to investigate short and long run interplay between variables through symmetric relationships. It is a limited approach since it doesn't have the ability to highlight possible asymmetries. This limit led to multiple essays to model asymmetric cointegration relationship between variables. One of the most recent models capturing the nonlinear relationship between variables and pointing out the influences of positive and negative shocks on the dependent variable in a single-equation structure is the Non-Linear Autoregressive distributed lag (NARDL) model, proposed by Ref. [94]. It is an extension of the ARDL model, initiated in Ref. [81].

This study investigates the asymmetric effects of COVID-19 full vaccination growth rate on S&P500 prices while controlling the EPU, OIL and GOLD price shocks. The general relationship between all variables is presented by the following linear regression model:

$$\Delta S\&P500_t = \alpha_0 + \lambda_1 VACR_t + \lambda_2 GOLD_t + \lambda_3 OILWTI_t + \lambda_4 EPU_t + \varepsilon_t,$$

where S&P500, VACR, GOLD, OILWTI, EPU and ε are respectively Standard and Poors stock market index price, US daily full vaccination growth rate against COVID-19, gold price, oil price, the US economic policy uncertainty index and error term. Additionally, Δ, α_0, λ_i, $i = 1$ *to* 4 respectively represent the first difference factor, the constant term and the independent variables coefficients.

We apply the non-linear auto-regressive distributed lag (NARDL) approach, proposed by authors in Ref. [94] to investigate the asymmetric connection between VACR, S&P500 prices, OILWTI, GOLD and EPU. The NARDL model is an extension of the linear ARDL model introduced by Ref. [81]. It is helpful in analyzing the long- and short-run asymmetric effects of both positive and negative components of full vaccination growth rate on S&P500 index. In addition, the NARDL model allows the analysis of the cointegration relations in small samples, the NARDL model performs better, Ref. [84]). To capture the effect of asymmetry, the NARDL approach decomposes the independent variables into partial sum of positive and negative change, which are both included as separate regressors in the model. Namely, positive and negative shocks might not have the same sign. Accordingly, the NARDL model is depicted as follows:

$$\begin{aligned}\Delta S\&P500_t = {} & \gamma_0 + \delta\ S\&P500_{t-1} + \delta_1^+ VACR_{t-1}^+ + \delta_1^- VACR_{t-1}^- + \delta_2^+ GOLD_{t-1}^+ \\ & + \delta_2^- GOLD_{t-1}^- + \delta_3^+ OILWTI_{t-1}^+ + \delta_3^- OILWTI_{t-1}^- + \delta_4^+ EPU_{t-1}^+ \\ & + \delta_4^- EPU_{t-1}^- + \sum_{j=1}^{k0} \gamma_{0j} \Delta S\&P500_{t-j} + \sum_{j=1}^{k1+} \gamma_{1j}^+ \Delta VACR_{t-j}^+ \\ & + \sum_{j=1}^{k1-} \gamma_{1j}^- \Delta VACR_{t-j}^- + \sum_{j=1}^{K2+} \gamma_{2j}^+ \Delta OILTI_{t-j}^+ + \sum_{j=1}^{k2-} \gamma_{2j}^- \Delta OILWTI_{t-j}^- \\ & + \sum_{j=1}^{k3+} \gamma_{3j}^+ \Delta GOLD_{t-j}^+ + \sum_{j=1}^{k3-} \gamma_{3j}^- \Delta GOLD_{t-j}^- + \sum_{j=1}^{k4+} \gamma_{4j}^+ \Delta EPU_{t-j}^+ \\ & + \sum_{j=1}^{k4-} \gamma_{4j}^- \Delta EPU_{t-j}^- + \varepsilon_t. \end{aligned} \tag{2}$$

In equation (2), the short-run asymmetric effects for positive changes of fully vaccination growth rate, oil and gold prices as well as the economic policy uncertainty are respectively given by γ_{1j}^+, γ_{2j}^+, γ_{3j}^+ and γ_{4j}^+ while the parameters for negative changes are γ_{1j}^-, γ_{2j}^-, γ_{3j}^- and γ_{4j}^-. Whereas, long-run asymmetric effects are respectively given by δ_{1j}^+, δ_{2j}^+, δ_{3j}^+ and δ_{4j}^+ for positive changes and by δ_{1j}^-, δ_{2j}^-, δ_{3j}^- and δ_{4j}^- for negative changes, normalized on δ_0.

Furthermore, as depicted by equations (3) and (4) defined below, the model's explanatory variables are decomposed into positive and negative changes following partial sum processes:

$$X_t^+ = \sum_{j=1}^{t} \Delta X_j^+ = \sum_{j=1}^{t} \max(\Delta X_j, 0). \tag{3}$$

$$X_t^- = \sum_{j=1}^{t} \Delta X_j^- = \sum_{j=1}^{t} \min(\Delta X_j, 0), \tag{4}$$

where X is a vector of the model's independent and control variables: VACR, GOLD, OILWTI and EPU. In fact, the increase in X represents the greatest change in X or 0, while the decrease is equal to the smallest change in X or 0.

The error correction form of the NARDL model, equation. (2), can be introduced as follows:

$$\begin{aligned}\Delta S\&P500_t = {} & \gamma_0 + \delta ECT_{t-1} + \sum_{j=1}^{k0} \gamma_{0j} \Delta S\&P500_{t-j} + \sum_{j=1}^{k1+} \gamma_{1j}^+ \Delta VACR_{t-j}^+ + \sum_{j=1}^{k1-} \gamma_{1j}^- \Delta VACR_{t-j}^- \\ & + \sum_{j=1}^{K2+} \gamma_{2j}^+ \Delta OILTI_{t-j}^+ + \sum_{j=1}^{k2-} \gamma_{2j}^- \Delta OILWTI_{t-j}^- + \sum_{j=1}^{k3+} \gamma_{3j}^+ \Delta GOLD_{t-j}^+ \\ & + \sum_{j=1}^{k3-} \gamma_{3j}^- \Delta GOLD_{t-j}^- + \sum_{j=1}^{k4+} \gamma_{4j}^+ \Delta EPU_{t-j}^+ + \sum_{j=1}^{k4-} \gamma_{4j}^- \Delta EPU_{t-j}^- + \varepsilon_t, \end{aligned}$$

where,

$$\begin{aligned} ECT_{t-1} = {} & S\&P500_{t-1} - \sigma_1^+ VACR_{t-1}^+ - \sigma_1^- VACR_{t-1}^- - \sigma_2^+ GOLD_{t-1}^+ - \sigma_2^- GOLD_{t-1}^- \\ & - \sigma_3^+ OILWTI_{t-1}^+ - \sigma_3^- OILWTI_{t-1}^- - \sigma_4^+ EPU_{t-1}^+ - \sigma_4^- EPU_{t-1}^-, \end{aligned} \tag{5}$$

where ε_t is the error term. It is independently and identically distributed with zero mean and constant variance. k represents the lag order. The long run asymmetric effects of the explanatory variables on the dependent variable are estimated by: $\sigma_1^+ = -\frac{\delta_1^+}{\delta}$, $\sigma_1^- = -\frac{\delta_1^-}{\delta}$,

$\sigma_2^+ = -\frac{\delta_2^+}{\delta}$, $\sigma_2^- = -\frac{\delta_2^-}{\delta}$, $\sigma_3^+ = -\frac{\delta_3^+}{\delta}$,$\sigma_3^- = -\frac{\delta_3^-}{\delta}$, $\sigma_4^+ = -\frac{\delta_4^+}{\delta}$, and $\sigma_4^- = -\frac{\delta_4^-}{\delta}$. The Short run asymmetric effects are estimated by $\sum_{j=1}^{k+} \gamma_j^+$ and $\sum_{j=1}^{k-} \gamma_j^-$.

The error correction term, as presented in equation (5), captures the speed of adjustment to the long-run equilibrium. In other words the related coefficient explains how long it takes to reach the long-run equilibrium under the explanatory variable shocks.

Our empirical study is mainly conducted in the four following steps. First, we need to check the stationarity of all model's variables through different unit root tests. In fact, the variables must be either stationary at level or first difference or both. Second, we need to verify that the order of integration of each variable is less than 2 (Refs. [81,82]) to conduct the Bound Test technique e.g. Ref. [81]. The bound test for cointegration provides two asymptotic critical values I (0) and I (1). If the F-statistic value is greater than the upper critical bound, I (1), then we can say that the variables are cointegrated and that there is a long-run relationship among them. We use equation (2), to test the null hypothesis of non-cointegration, ($\delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$), which means there is no long-run effect between the model's variables. While, the alternative hypothesis ($\delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$), means the existence of long-run effect between the model's variables. Third, after the cointegration among the variables is validated, estimation for short-run and long-run coefficients can be implemented. Note that before proceeding with the estimations, we applied the natural log to the model's variables. Finally, we check the model's stability by Cumulative Sum of Recursive Residuals (CUSUM), then we plot asymmetric dynamic multipliers graphs to explore how the model's dependent variable (S&P500) adjusts to its new long-run equilibrium following a negative or positive shock in our model's independent variables (VACR, OILWTI, GOLD and EPU) as follows:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial S\&P500_{t+j}}{\partial VACR_t^+}, m_h^+ = \sum_{j=0}^{h} \frac{\partial S\&P500_{t+j}}{\partial OILWTI_t^+}, m_h^+ = \sum_{j=0}^{h} \frac{\partial S\&P500_{t+j}}{\partial GOLD_t^+}, m_h^+ = \sum_{j=0}^{h} \frac{\partial S\&P500_{t+j}}{\partial EPU_t^+},$$

$$m_h^- = \sum_{j=0}^{h} \frac{\partial S\&P500_{t+j}}{\partial VACR_t^-}, m_h^- = \sum_{j=0}^{h} \frac{\partial S\&P500_{t+j}}{\partial OILWTI_t^-}, m_h^- = \sum_{j=0}^{h} \frac{\partial S\&P500_{t+j}}{\partial GOLD_t^-}, m_h^- = \sum_{j=0}^{h} \frac{\partial S\&P500_{t+j}}{\partial EPU_t^-}.$$

m_h^+ illustrates how S&P500 index prices traverses along the ways from the short to the long-run on account of a positive change in the explanatory variables. While, m_h^- indicates how S&P500 index traverses along the ways from the short to the long run on account of a negative change in the explanatory variables.

If $h \to \infty$ then, $m_h^+ \to \sigma_i^+$ and $m_h^- \to \sigma_i^-$ for $i = 1$ to 4. These dynamic multipliers express the cumulative effects of positive and negative shocks on the four explanatory variables from an initial equilibrium to the new equilibrium as illustrated by Shin et al. (2014).

4. Empirical results and discussion

According to the Augmented Dickey-Fuller, Phillips-Perron and Dickey-Fuller-GLS tests (Table 5), we show that Economic Policy Uncertainty is stationary at level I(0) while, oil price, S&P500 index, COVID-19 vaccination and gold price are non-stationary at level I(0). Therefore, to analyze the shock (positive or negative) between the research variables, we had to transform the non-stationary variables (gold price, oil price, S&P500 and COVID-19 vaccination) to the first difference form to make all the variables stationary and to achieve effective results. On the other hand, the breakpoint test confirms the Augmented Dickey-Fuller, Phillips-Perron and Dickey-Fuller-GLS tests that EPU is stationary at level I(0) while GOLD, OILWTI, S&P500 and VACR are stationary at the first difference and suggesting that no I(2) variable is involved. The Breakpoint unit root test selects a single break date where the Dickey-Fuller -statistic is minimized.

As it is important to identify an optimal lag length in order to estimate the proposed NARDL model, we follow AIC criteria, Ref. [4].

We apply the NARDL approach after checking the necessary conditions. The NARDL model results are exposed in Table 6a and Table 6b, indicating the existence of cointegration between the model's variable at the significance level of 1% and reveals that the previous shocks in S&P500 have a significant negative impact on the current value of S&P500 index price (-0.327858). Furthermore, the short run and long run asymmetric influence of Full vaccination growth rate and control variables (OILWTI, GOLD and EPU) on S&P500 using the NARDL model are presented in Table 6a.

In fact, it is shown that both positive and negative shocks of full vaccination growth rate on the same day do not affect the S&P500 index, since the p-value is not significant. Besides, the results indicate that both negative and positive shocks of delayed full vaccination growth have a negative effect on the S&P500 index, in the short term.

A positive one lag shock of full vaccination growth rate negatively impact the S&P500 index price with a coefficient of −0.447468. On the other hand, one lag negative shocks of full vaccination growth rate also negatively influence the S&P500 index price with a coefficient of −0.389873. Hence, as shown in Table 6a,6b, the COVID-19 fully vaccination growth rate positive shocks influence negatively the S&P500 index with one, three, and five lagged days. On the other hand, the negative shocks of the COVID-19 full vaccination growth rate also influence negatively the S&P 500 index value with a lag of one, two, four and six lagged days. We confirm that in the short run, the US stock market reacts negatively to the positive and negative shocks of the COVID-19 full vaccination growth rate. Therefore, the results indicate that increases or declines in COVID-19 full vaccination have negative effects on the S&P500 index, in the short run. This result is consistent with Refs. [49,76], especially for developed countries.

From a first point of view, this impact is explained by the persistence of security restrictions during the start of the COVID-19 vaccination period. Therefore, the news on the number of complete vaccines does not have a positive impact in the short run.

Table 5
Unit root and breakpoint test results.

Level I(0)						
Method		EPU	GOLD	OILWTI	S&P500	VACR
ADF test	Constant	-9.500681***	-1.902832	-0.201115	-0.996639	-3.125025**
	constant & trend	-10.60810***	-1.958968	-1.812292	-3.877934**	-2.186434
PP test	Constant	-10.20087***	-2.032849	-1.926410	-0.818740	-1.391165
	constant & trend	-10.87702***	-2.085286	-1.555802	-3.830832**	0.524661
DF-GLS	Constant	9.330972***	-1.352826	-0.674830	0.552964	-1.651865
	constant & trend	-10.49281***	-1.640038	-1.845045	-3.885356***	-3.28249**
Breakpoint	Constant	-11.3988*** (22/3/2021)	-2.535034 (30/3/2021)	-3.482416 (21/5/2021)	-2.299995 (31/3/2021)	-2.000717* (25/3/2021)
	constant & trend	-11.7281*** (22/3/2021)	-3.195154 (30/3/2021)	-3.352385 (21/5/2021)	-4.993352* (31/3/2021)	-4.381594 (25/3/2021)
First difference I(1)						
Method		EPU	GOLD	OILWTI	S&P500	VACR
ADF test	Constant	-12.63455***	-11.01021***	-12.90073***	-10.17560***	-13.71437***
	constant & trend	-12.58909***	-10.97129***	–13.03493***	-10.14020***	14.0520***
PP test	Constant	-72.36779***	10.95886***	13.17954***	-13.27265***	-11.9390***
	constant & trend	-68.60494***	-10.91623***	-13.60332***	-13.22165***	-11.8855***
DF-GLS	Constant	-12.16117***	-3.395965***	-2.103433**	-3.438865***	-2.755581***
	constant & trend	-12.58339***	-9.172823***	-11.05304***	-10.93229***	10.765899***
	constant	-21.06954*** (2/1/2021)	-11.54383*** (26/2/2021)	-13.24058*** (22/7/2021)	-13.46807*** (27/1/2021)	-11.08516*** (4/2/2021)
	Constant& trend	-20.99702*** (2/1/2021)	-11.54223*** (26/2/2021)	-13.32334*** (22/7/2021)	13.43664*** (27/1/2021)	-12.48984*** (4/2/2021)

Source: The authors' calculations from EViews
Notes: ***,**,* present significance at level 1%, 5%, and 10% respectively.

This makes sense in the context where hesitation due to misinformation about vaccination and lack of confidence regarding the effectiveness of the new COVID-19 vaccine persists.

From another point of view, this implies that increasing the rate of vaccination against COVID-19 on the one hand and gradually easing the distancing measures on the other hand, leads to an increase in the rate of infection. Thus, these procedures have an indirect negative impact on the stock market. This means that investor confidence in the stock market has not been restored in the short run even with the vaccination growth rate because of the continued rise in infection and death rates and the news warning of the appearance of other variants.

Despite massive vaccination campaigns and countries' efforts to stock up on vaccine doses, there is some doubt about the rapid approval of the new COVID-19 vaccine. The feeling of fear and anxiety restore during the vaccination period with the announcement of the delta variant at the end of 2020, e.g. Ref. [16]. Moreover, this finding corroborates the results in Ref. [100] indicating the rise in stock market volatility following the emergence of two variants (omicron and delta).

In addition, positive and negative short run shocks of OILWTI on the day do not affect S&P500 index prices on the same day. This is explained by the difficulty for the oil production and price to react favorably and to adjust in the short term quickly to the increases in full vaccination. In times of stress, it is problematic to be able to examine the impact of oil on other financial assets as it depends on the epidemiological situation and other related politico-economic factors.

Furthermore, we realize that only negative short run shocks of gold price affect positively the S&P500 index price, where, a 1% decrease in the gold price causes a decrease about 0,2986% of the stock market index value. Which means that a decrease in gold price about 1% is accompanied by a drop in the stock market index on the same day. While, the gold positive shocks have a positive impact on the US stock market after four to six days in the short term.

Moreover, short run positive as well as negative shocks of EPU do not affect the S&P500 index on the same day. While, both negative and positive delayed shocks of EPU have positive dynamic effects on S&P500 index price. The results, exposed in Table 6a,6b, indicate that the raise of EPU has a positive and significant influence on the US stock market. In fact, a positive shock of delayed EPU leads to an increase of the S&P500 index price with a coefficient of 0.006975. While, a negative delayed shock of EPU leads to an increase of the stock market index with a coefficient of 0.005638.

The examination of the long-term relationship between the variables of the study show that the past values of the S&P500 have a significant and negative impact on the current values of the S&P500. This result is consistent with Ref. [40] and contrasts with Ref. [102]).

A positive (negative) long run shock of full vaccination growth rate increase the S&P500 index price with the coefficient 0.408583 (0.409064). In other words, full vaccination growth rate has a long run positive and significant impact on S&P500 index. The positive as well as negative long-run asymmetric impact of VACR with one lag are respectively 1.246218 (- $\frac{0.408583}{-0.327858}$) and 1.247686 (- $\frac{0.409064}{-0.327858}$). It implies that 1% increase of the US full vaccination growth rate leads to 1.246218% increase in the S&P500 index price. Similarly, 1% decrease in the US full vaccination growth rate leads to 1.247686% decrease in the S&P500 stock market price.

Table 6a
Short-run and long-run asymmetries.

Dependent variable	Coefficients	t-statistics			
$S\&P500_{t-1}$	-0.327858***	-5.022416			
Explanatory variables		Short-run asymmetries			Long-run asymmetries
	Coefficients	t-statistics		Coefficients	t-statistics
$\Delta VACR^{+}$	0.033765	0.770997			
$\Delta VACR^{-}$	-0.033347	-0.262502			
$\Delta VACR^{+}{}_{t-1}$	-0.447468**	-2.121525	$VACR^{+}{}_{t-1}$	0.408583***	1.833770
$\Delta VACR^{-}{}_{t-1}$	-0.389873**	-2.066246	$VACR^{-}{}_{t-1}$	0.409064***	1.923392
$\Delta VACR^{+}{}_{t-2}$	-0.319395***	-2.415394			
$\Delta VACR^{-}{}_{t-2}$	-0.371250***	-3.881469			
$\Delta VACR^{+}{}_{t-3}$	-0.382514***	-3.513571			
$\Delta VACR^{-}{}_{t-3}$	-0.044259	-0.498060			
$\Delta VACR^{+}{}_{t-4}$	-0.003138	-0.030594			
$\Delta VACR^{-}{}_{t-4}$	-0.178936**	-2.272716			
$\Delta VACR^{+}{}_{t-5}$	-0.197898**	-2.179767			
$\Delta VACR^{-}{}_{t-5}$	-0.014734	-0.528703			
$\Delta VACR^{-}{}_{t-6}$	0.051739**	2.138775			
$\Delta OILWTI^{+}$	0.045640	0.873153	$OILWTI^{+}{}_{t-1}$	0.161435***	3.563390
$\Delta OILWTI^{-}$	0.070471*	1.629172	$OILWTI^{-}{}_{t-1}$	-0.017285	-0.967080
$\Delta GOLD^{+}{}_{t-1}$	0.049063	0.352477	$GOLD^{+}{}_{t-1}$	-0.112021**	-2.207773
$\Delta GOLD^{+}$	0.064678	0.471386			
$\Delta GOLD^{+}{}_{t-2}$	-0.057445	-0.455365			
$\Delta GOLD^{+}{}_{t-3}$	-0.020992	-0.167898			
$\Delta GOLD^{+}{}_{t-4}$	0.427721***	3.536234			
$\Delta GOLD^{+}{}_{t-5}$	0.389677***	3.155335			
$\Delta GOLD^{+}{}_{t-6}$	0.413185***	3.423901			
$\Delta GOLD^{-}$	0.298591***	2.714470	$GOLD^{-}{}_{t-1}$	0.007819	0.182261
ΔEPU^{+}	0.001182	0.420413			
ΔEPU^{-}	0.001950	0.685385			
$\Delta EPU^{+}{}_{t-1}$	0.006975**	2.112521	$EPU^{+}{}_{t-1}$	-0.007270**	-2.162865
$\Delta EPU^{+}{}_{t-2}$	0.007030***	2.394752			
$\Delta EPU^{+}{}_{t-3}$	0.007511***	2.913703			
$\Delta EPU^{+}{}_{t-4}$	0.008436***	3.308130			
$\Delta EPU^{+}{}_{t-5}$	0.005683**	2.287677			
$\Delta EPU^{-}{}_{t-1}$	0.005638*	1.878189	$EPU^{-}{}_{t-1}$	-0.004070	-1.181441
Diagnostic test results					
R-squared	0.988205	Mean dependent var		8.328501	
Adjusted R-squared	0.983579	S.D. dependent var		0.047860	
S.E. of regression	0.006133	Akaike info criterion		−7.114712	
Sum squared resid	0.003837	Schwarz criterion		−6.265225	
Log likelihood	549.7019	Hannan-Quinn criter.		−6.769521	
F-statistic	213.6353	Durbin-Watson stat		2.021636	
Prob(F-statistic)	0.000000				
Cointegration Bounds Test					
Test Statistic	Value	Signif.	I(0)	I(1)	
F-statistic	5.695670	10%	1.95	3.06	
k	8	5%	2.22	3.39	
		2.5%	2.48	3.7	
		1%	2.79	4.1	

Notes: ***,**,* present significance at level 1%, 5%, and 10% respectively.
(+) positive partial sum, (-) negative partial sum.
Sample size adjusted from January 14, 2021 - August 20, 2021.
S&P500: Standard and Poors stock market index,
VACR: the daily full vaccination growth rate against COVID-19,
OILWTI: Oil price, GOLD: Gold, EPU: Economic Policy Uncertainty.

This finding implies that over the long run, the effect of an increase of COVID-19 full vaccination growth rate on the S&P500 index appears to be equal to the impact of a decline of COVID-19 full vaccination growth rate in the US stock market. Thus, we confirm the approximately symmetric impact of the COVID-19 full vaccination growth shocks on the stock market. In the long run, we assume that the US stock market reacts positively to the increase in vaccination growth rate and negatively (deteriorates) in response to the decline in the COVID-19 full vaccination growth rate. This finding corroborates that of Refs. [30,50,55,67,69,86,18]. This study result aligns with those found by Ref. [34] who found that several stock index values such as: CAC40, S&P500, LFTSE CHINA A50, LFTES MIB, MASI and LIBEX35, are sensitive to positive and negative shocks of COVID-19 cases and deaths. This implies that the stock market in a pandemic period transferred to an economic crisis reacts to all shocks.

Table 6b
NARDL cointegration and long-run form.

variable	Coefficients	t-statistics	variable	Coefficients	t-statistics
CointEq(-1)	-0.327858 ***	-7.435153			
Long run Asymmetric impact					
$VACR^{+}$	1.246218 **	2.083195	$VACR^{-}$	1.247686 **	2.180931
$OILWTI^{+}$	0.492394***	3.164796	$OILWTI^{-}$	-0.052720	-0.913462
$GOLD^{+}$	-0.341674 **	-2.126830	$GOLD^{-}$	0.023849	0.184444
EPU^{+}	-0.022173**	-2.001329	EPU^{-}	-0.012415	-1.201166

Notes: ***,**,* present significance at level 1%, 5%, and 10% respectively.
(+) positive partial sum, (-) negative partial sum.
Sample size adjusted from January 14, 2021 - August 20, 2021.
S&P500: Standard and Poors stock market index,
VACR: the daily full vaccination growth rate against COVID-19,
OILWTI: Oil price, GOLD: Gold, EPU: Economic Policy Uncertainty.

Regarding the long run effects of the control variables, it is found that a positive shock in OILWTI has a significant positive impact on S&P500 with a coefficient of 0.161435. In fact, we find out that the long-run coefficient of $OILWTI^{+}$ is 0.492394 (- $\frac{0.161435}{-0.327858}$). Therefore, for a 1% increase in the crude oil price, the US stock market responds with a 0.49% rise. As a result, we admit that a positive shock of oil price shock has a significant and positive impact on the US stock market in long term and this finding is consistant with Refs. [98,110]. We explain this relationship by the fact that the $S\&P500$ index is composed by a large number of industrial companies, so the return of the oil production and trade, after the appearance of vaccines against the COVID-19 leads to refreshing the activity of these listed companies and increasing their market value.

We confirm that the dynamic dependence between oil and stock market prices intensifies during financial crises, e.g. Ref. [90], but also during health and economic crises such as the COVID-19 pandemic.

The long run shocks of GOLD lead to a significant decline in S&P500 with a coefficient of 0.112021. Hence, the long-run asymmetric effect of $GOLD^{+}$ is -0.341674 (-$\frac{-0.112021}{-0.327858}$). Which indicates that a positive shock in gold price generates a decline of 0.34% in the S&P500 index price. The results demonstrate that a positive shock of gold price has a negative impact on the S&P500 stock index value. This result supports the conclusion of Ref. [9], who exposed a negative relationship between stock market volatility and gold price. Indeed, the investors' behavior during financial crises consists in protecting their money against the risk of loss by approving gold. This asset is considered a safe haven. It is also the most liquid investment asset. Thus, in times of crisis, by tradition, investors tend to invest more and more in gold to keep the value of their wealth. Therefore, the gold price rises and the higher it goes, more investors are attracted to this commodity. During these times of instability, they are less confident in making gains on stock market assets, especially by noticing the increase in gold price that announces a significant demand, which giving alert to a crisis situation. This phenomenon indirectly drops the stock market index price. This conclusion allows us to confirm the characteristic of gold as a safe haven asset also during this health and economic crisis, e.g. Refs. [15,112].

This result submits that even with a vaccine, the pandemic is still not completely under control and that the decrease in the stock market is due to investors' preference for other assets like gold. It should be noted that when economic policies are uncertain, demand for stock is shrinking against the growing demand for gold, due to "flight to quality" effects, Ref. [42]. By noticing a decrease in the gold demand with the resumption of some economic stability, the demand for equities increases. We admit the existence of a symmetrical relationship between the gold and equity markets.

By the same way, we notice a significant long run coefficient of EPU (-0.007270) leading to an asymmetric long-run impact of EPU^{+} by -0.022173 (- $\frac{-0.007270}{-0.327858}$), implying to the existence of a negative and dynamic relationship between the $S\&$P500 index value and the Economic Policy Uncertainty Index (EPU). Wherefore, 1% increase in EPU engenders a decrease of 0.022% in S&P500. Hence, a positive shock of EPU affects negatively the US stock market. This conclusion corroborates those of Refs. [92,108,112,102].

We find no significant effects of the negative shocks of EPU, OIL and GOLD prices on the S&P500 index. The coefficients of $OILWTI^{-}$, $GOLD^{-}$ and $USEPU^{-}$ are in that order- 0.52720 (-$\frac{-0.017285}{-0.327858}$), 0.023849 (-$\frac{0.007819}{-0.327858}$) and -0.012415 (-$\frac{-0.004070}{-0.327858}$), but their p-values are not significant.

Based on these coefficients, we assume that a pullback in OILWTI, GOLD and EPU of around 1% each cause respectively: an upside of around 0.053%, a downside of 0.024% and a 0.012% rise in the S&P500 as a result. In addition, we suppose that the effect of the negative shocks of EPU, crude oil and gold prices on the US stock market value appears to be less than that of their positive shocks.

Moreover, long-run relationships between VACR, OILWTI, GOLD, and S&P500 are confirmed through the NARDL bounds test. The result (Table 6a,6b) demonstrates that the R-squared value of 0.988205 and Adj. R-squared value of 0.983579l indicated that the overall model is robust. In addition, the CointEq (ECM) is found to be statistically significant and negative in sign (-0.327858), which confirms the robustness of the model. A steady long-run relationship between the variables under study exists. Moreover, F-statistics (Table 6a) suggest that the model is well fitting based on the estimated p value.

The stability of the long-run coefficient is examined along with the short-run dynamics. To this end, we follow Ref [115] and implement the CUSUM test, as suggested by Ref [24], based on the cumulative residuals. As shown in Fig. 1, the residuals remain within the critical limits of the 5% significance level. According to these results, the estimated long-run regressors remain stable over the considered period of study.

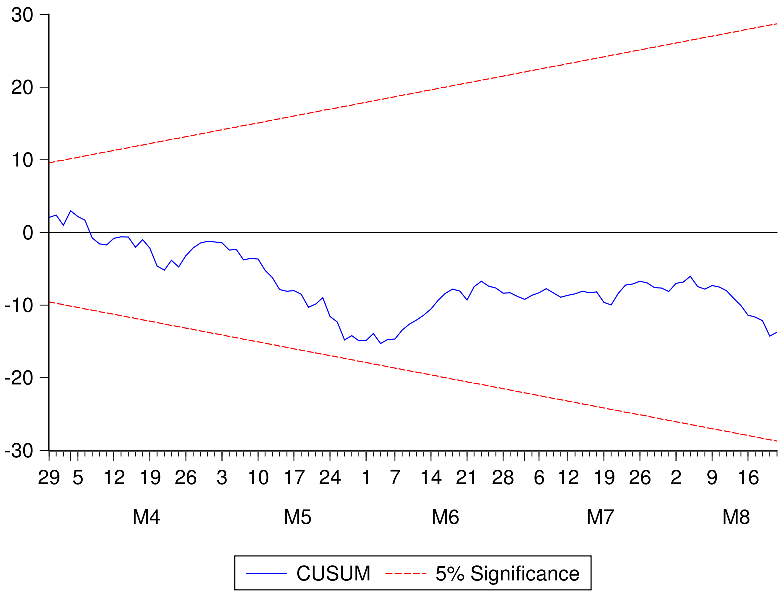

Fig. 1. NARDL CUSUM tests.

Finally, as it is important to explore the dynamic multiplier behavior of the temporal dynamics of the S&P500 index price through short and long run dynamic shocks of full vaccination growth rate as well as EPU, GOLD and OILWTI, we investigate the dynamic multipliers. Besides, it provides more insights into the statistical validity of the asymmetric results reported in Table 6a.

The continuous black line, in Fig. 2, shows how the dependent variable adjusts over the horizon to a positive shock in the independent variables and the dashed black line illustrates the adjustments of the dependent variable over the horizon due to a negative shock in the independent variables. The dashed red line indicates the asymmetry plots, and it reflects the difference between the dynamic multipliers of positive and negative changes in the regressors. We can clearly see through Fig. 2 that it takes about 5 to 6 periods of time for the multipliers before reaching a relatively stable impact.

A set of 4 dynamic multipliers graphs plotted for the NARDL model and presented by Fig. 2 in order to evaluate the adjustment of asymmetry in the operating long-run equilibrium after moving to a new long-run equilibrium as a result of negative and positive shocks.

Fig. 2-a shows that unitary decreases in US full vaccination growth rate (dash line) have lower effects than unitary increases (continuous line) in the short time, which takes about 4 periods to observe a series of ups and downs between negative and positive shocks of VACR on S&P500. In the long run, after 11 periods we can see an adjustment to a new equilibrium where a decrease in the US full vaccination growth rate (VACR-) has an asymmetric effect as an increase (VACR+) on the S&P500 index price.

In Fig. 2-b, the short-run equilibrium demonstrates that unitary decreases in the oil price (dash line) have higher effects than unitary increases (continuous line). The adjustment takes about 2 periods to observe the correction. The new long-term equilibrium shows that the level of effect of oil price positive shocks on the S&P500 index price has a more significant long-term impact than negative shocks.

Fig. 2-c indicates that the amplitude of the negative shock of the EPU dominates the positive shock in the long-run. The results are consistent with the survey by Ref. [94] according to which the decrease in uncertainty indicates a good economic outlook. This illustration confirms that the S&P500 index price depends negatively on the economic policy uncertainty, in the long run. When economic uncertainty increases, the stock market index falls. On the other hand, this latter is removed in the event of the diminution of economic uncertainty.

Fig. 2-d reveals that gold price negative shocks appear to have a higher impact on the S&P500 index price than positive shocks in the short-run while it seems to be different in the long-run equilibrium, where gold positive shocks have higher effect than negative shocks on S&P500 value. The adjustment takes about 7 periods to observe the correction.

The first bright spot in these results is that the impact of positive or negative shocks from COVID-19 full vaccination growth on the stock market in the short run differs from that in the long run. In fact, the positive shocks and negatives of COVID-19 full vaccination growth affect the stock market positively in the long-run and negatively with delay in the short-run.

The second bright spot of these findings is that positive and negative shocks of COVID-19 full vaccination growth have a symmetrical and equal impact of the COVID-19 full vaccination growth shocks on the S&P500 index in the long run. Consequently, the US stock market reacts similarly to positive and negative COVID-19 full vaccination growth shocks.

The third bright spot in this study is that the increase in the COVID-19 full vaccination growth offers immunity to the US stock market in the long-run.

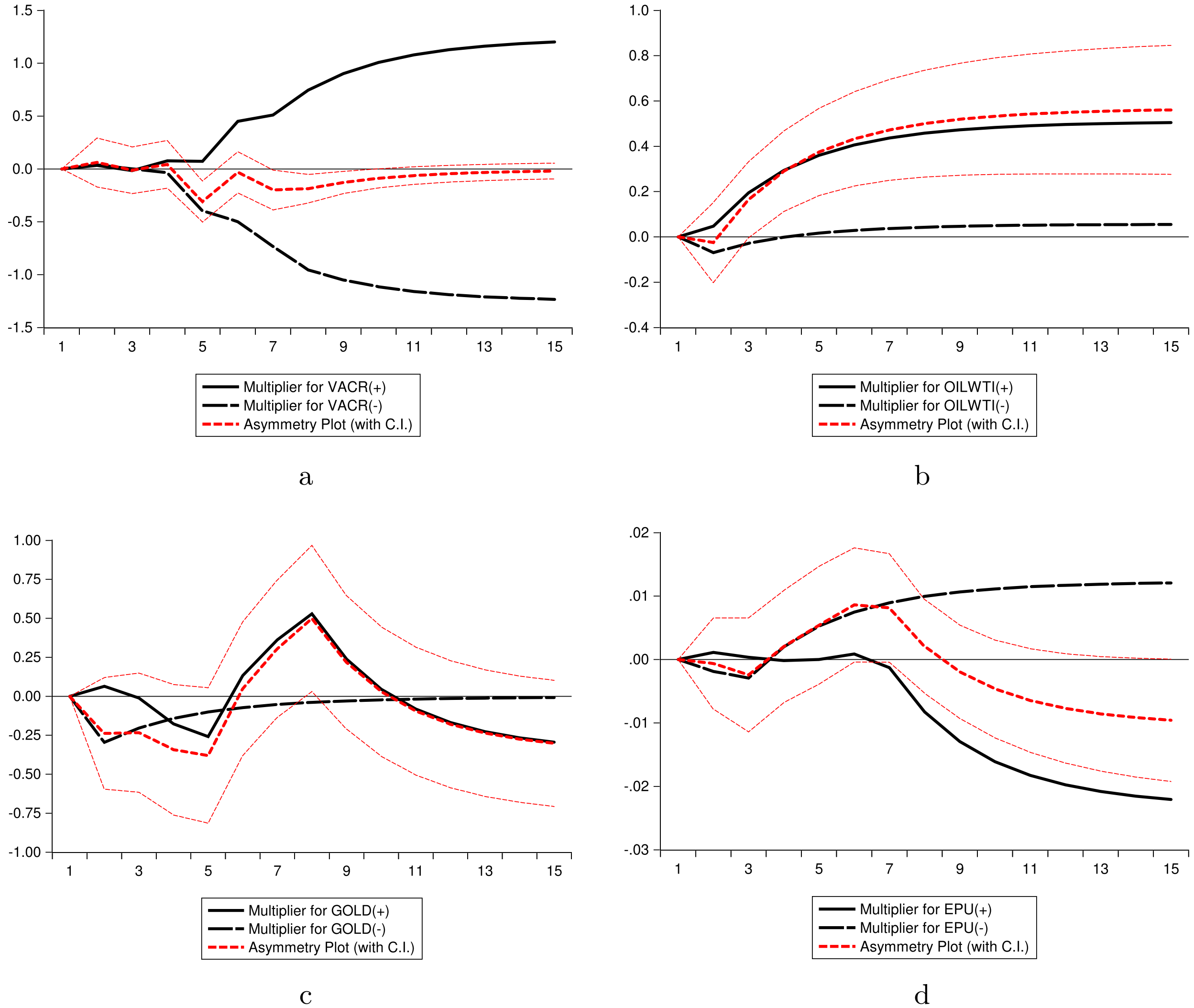

Fig. 2. Dynamic multipliers graphs.

5. Conclusion

The spread of the COVID-19 pandemic and the subsequent protective measures have had an unprecedented impact on the socioeconomic situation in most countries, including the United States. The development of full COVID-19 vaccination in early 2021 gives hope for a resumption of economic activity and the stabilization of the stock market.

The goal of applying vaccination against COVID-19 is primarily to develop human immunity; does it accomplish that in immunizing the S&P 500 index against the COVID-19 crisis? Our study sheds light on this question by assuming that vaccination should positively boost investor sentiment and therefore the US stock market.

This research contributes to filling the gap of limited studies related to the literature on COVID-19 vaccination and the stock market. This study is the first to examine the reaction of the US stock market to positive and negative shocks from the growth of full vaccination against COVID-19 in the long and short term.

To achieve the objective of the study, the nonlinear autoregressive Distributed lag approach was applied to daily time series data from January 14, 2021 to August 20, 2021. The results specify that over the long-run, the American stock market reacts positively to the positive and negative shocks of COVID-19 full vaccination growth. Thus, the study confirms the symmetric impact of COVID-19 full vaccination growth shocks on the stock market. In contrast, the short-term results indicate that increases and decreases of the COVID-19 full vaccination growth have a negative effect on the S&P500 index, with some delays.

However, the study findings provide good insights: First, we discover that the US full vaccination against COVID-19 immunizes correspondingly S&P500 index in the long run. Second, the US stock market reacts similarly to positive and negative shocks of COVID-19 full vaccination growth. The third bright spot of these results is that the impact of positive or negative shocks of COVID-19 full vaccination growth on the stock market in the short run differs from that in the long run.

Furthermore, study results show that gold positive shocks have a negative impact on the S&P 500 index. This is justified by the fact that in presence of political and economic uncertainty, the demand for equities declines in favor of the rising demand for gold, due to the “flight to quality” effect. The analysis results prove the existence of a dynamic and negative relationship between the S&P500 and the economic policy and uncertainty index.

- Policy implications and recommendations

We argue that the government should reexamine vaccination and protection policies against COVID-19 in light of the negative consequences we describe. Mass vaccination was not sufficient in the short term, implying that the government would have to take extreme measures regarding compliance and the extended effects of COVID-19 to manage the pandemic and improve investor concerns. It is essential for the government to control the spread of infections by continuing the lockdown to avoid new contaminations even before the implementation of the vaccination against COVID-19. The government derives advantages from our research by retaining through the results the role of optimizing safety programs and media awareness of COVID-19 vaccination.

In fact, the APT theory hypothesis has been confirmed in this paper by showing that people who are worried about the COVID-19 virus, also worry about the risks associated with the vaccination use and are reluctant to get the vaccine in the short term. For this reason, they tend to know more about vaccines. On this basis, the government should disseminate enough information about vaccines in the media to reduce concerns about the risks of vaccination and hesitancy to get vaccine against COVID-19 19.

In light of the results of this study, the government should communicate safety and efficacy indicators, which make investors more confident about the COVID-19 vaccine during the pandemic and helps to bring socioeconomic activities back to normal.

Taking into account the above findings, policymakers are advised to implement policy measures and strategies to stimulate investors’ confidence in times of a pandemic through the disclosure of detailed information on the effectiveness of vaccines and announcing programs of financial assistance to investors and support for companies which reduces the feeling of panic, anxiety and fear.

Other recommendations are also highlighted and addressed to investors. First, they need to learn a lesson from this pandemic by adopting an asset diversification strategy and incorporating well-diversified stocks (such as those in the energy and telecommunications sectors) in their equity portfolios. They are advised to apply a risk management approach to realize gains in times of economic and/or health crisis. On the other hand, investors should support their financial assets during a pandemic to maintain stock market stability in the presence of policies that must time to restore economic activity. Furthermore, it is relevant for investors to equip themselves with developed tools to facilitate stock market forecasts and have strategies for effective hedging in the event of future crises.

- Limitations and Future Research

Finally, like any scientific study, this one is not free from limitations that can open up avenues for future research. The main limitation of this survey is the sampling period. Thus, the role of COVID-19 full vaccination in immunizing the stock market needs to be further highlighted using a longer data sample covering both phases: pre- and post-emergence of COVID-19 variants in order to deepen this study by verifying whether the impact of the full vaccination growth on the stock market varies between the two intervals.

In spite of the fact that we chose in this study the US stock market as the benchmark of global economic health to examine its response to COVID-19 full vaccination shocks, future researchers can test whether stock markets of other countries are reacting in the same way or whether they respond based on cultural perspectives on vaccination, citizen’s vaccination acceptance or retency, as well as the media coverage adopted for vaccination awareness.

Although, this research was restricted to study the impact of full vaccination growth on the stock market and as the COVID-19 crisis hit all economic activity, future studies can compare the reactions of stock markets, commodity markets and currency markets to the full vaccination growth. Its results will help investors identify which markets will recover faster in case of future pandemics.

Even though, we are content to study the reaction of the American stock market as a whole by choosing the S&P500 index, but we are still curious about the reaction of different sectors of the US stock market separately to the COVID-19 full vaccination growth shocks and which ones respond more quickly and positively. This may inspire future explorations to determine the sectors that will respond more quickly and positively.

A final suggestion for future research deserves clarification regarding the examination of the role of technological changes behind health inventions and vaccination on macroeconomic variables.

Additional information

No additional information is available for this paper.

Statistical resources

Authors’ calculations from EViews. Version 12.

CRediT authorship contribution statement

Hanen Atri: Conceived and designed the analysis, Analyzed and interpreted the data, Contributed analysis tools or data, Wrote the paper.

Hanen Teka: Conceived and designed the analysis, Analyzed and interpreted the data, Contributed analysis tools or data, Wrote the paper.

Saoussen Kouki: Conceived and designed the analysis, Analyzed and interpreted the data, Contributed analysis tools or data, Wrote the paper.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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