World pandemic uncertainty and German stock market: evidence from Markov regime-switching and Fourier based approaches

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Abstract
This study aims to examine the impact of the world pandemic uncertainty index on the German stock market index (DAX index) for the 1996Q1 to 2020Q3 period while controlling real effective exchange rate, industrial production index, and consumer price index. The present study performs the Fourier Augmented Dickey-Fuller Unit Root, Fourier Engle-Granger Cointegration, Bayer-Hanck Cointegration, and Markov switching regression tests. The outcomes disclose that there is a long-run cointegration association between the stock market index and world pandemic uncertainty index, real effective exchange rate, industrial production index, and consumer price index in Germany, indicating that the combination of these factors significantly affects the German stock market index in the long-run. Moreover, in both high and low volatile regimes, the world pandemic uncertainty index and real effective exchange rate negatively affect the German stock market index while industrial production and consumer price indices impact positively.

Keywords Stock market · World pandemic uncertainty · Regime switching · Fourier Engle-Granger cointegration · Germany

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1 Introduction

Numerous studies underscored that the development of stock markets could enhance long-term economic activities, and firms operating in countries with well-organized and efficient stock markets have more access to capital markets and experience a higher number of investment opportunities (Levine and Zervos 1996; Caporale et al. 2004; Naik and Padhi 2015). While stock market development could contribute positively to a country’s economic growth, the negative internal and external shocks unfavorably impact stock markets resulting in the deterioration of a country’s economy (Jonung and Roeger 2006; Smith et al. 2011). In the same vein, prior studies (e.g., Hassan et al. 2003; Ko and Lee 2015; Mnif 2017) underlined that stock markets significantly react to the negative shocks, and a rise in country risk and global uncertainty leads to increasing return volatility of stock markets and decreasing stock prices. More specifically, empirical studies provided significant evidence that stock markets are negatively impacted by world disease outbreaks shock. For instance, Nippani and Washer (2004) found that Severe Acute Respiratory Syndrome (SARS) outbreak has an adverse and significant effect on China and Vietnam stock markets. Ichev and Marinić (2018) revealed that the Ebola epidemic events adversely impacted the financial markets, returns.

Remarkably, by spreading the COVID-19 pandemic, the interest of numerous scholars has considerably triggered to investigate the effect of COVID-19 on global stock markets. The recent empirical studies (e.g., Anh and Gan 2020; Ashraf 2020b; Aggarwal et al. 2021) highlighted that stock markets are adversely affected by spreading the COVID-19 pandemic. Besides, studies (e.g., Erdem 2020; Zhang et al. 2020) showed that the COVID-19 pandemic positively impacts the volatility of international stock markets. Moreover, the empirical studies (Liu et al. 2020; Xiong et al. 2020; Uddin, Chowdhury, Anderson, and Chaudhuri 2021; Fernandez-Perez et al. 2021; Mazur, Dang, and Vega 2021; Narayan, Gong, and Alihamed 2021) suggested that the stock markets have a heterogeneous reaction to the COVID-19 outbreaks depending on firm-specific characteristics, type of sector, culture, income level, and economic strength.

What about the effect of world pandemic uncertainty on stock markets? Although some scholars have assessed the effect of specific disease outbreaks (e.g., SARS) on stock markets for the short-time period as cited above, limited studies were found to test the influence of world pandemic uncertainty on stock markets for the long period in general and Germany in particular. Notably, Germany has the biggest economy in the EU, and also has the largest exchange, based on the market capitalization, in Continental Europe (Brida and Risso 2010). Besides, the statistics disclosed that the German stock market is exposed to spreading the COVID-19, so that Deutsche Börse Group’s net revenue declined by − 4% to €707.5 million in 2020Q3, which was €733.8 million in 2019Q3.¹ Moreover, unlike prior studies, there is less attention has been paid by scholars to examine the effect of world pandemic uncertainty on stock markets deeply by considering the different regimes. Thus, the present study fills this gap and contributes by assessing the influence of the world pandemic uncertainty index on the German stock market index by considering the different regimes for the wide range between 1996Q1 and 2020Q3. The present study also contributed by using newly developed and novel econometrics techniques, namely Fourier

¹ https://deutsche-boerse.com/dbg-en/investor-relations/financial-reports/interim-reports.
Augmented Dickey–Fuller (Fourier ADF) Unit Root, Fourier Engle-Granger Cointegration, Bayer-Hanck Cointegration, and Markov switching regression tests.

The findings of this study have remarkable policy implications. First, the results reveal that there is a long-run cointegration relationship between the stock market index and world pandemic uncertainty index, real effective exchange rate, industrial production index, and consumer price index in Germany. Second, the results reveal that in both high and low volatile regimes, the world pandemic uncertainty index and real effective exchange rate negatively affect the German stock market index while industrial production and consumer price indices impact positively. This finding suggests that economic growth in Germany makes the stock market better functioning and efficient. This finding can be supportive evidence for the demand-leading hypothesis, which underlines the importance of economic growth on the stock market’s performance. Moreover, the investors in the German stock market index should prepare themselves against the exchange rate depreciations and pandemic uncertainty in today’s world. To the best of our knowledge, this is the first study investigating this relationship, and the outcomes of the present study are useful and open a new debate in the related literature.

The paper structure is as follows. Section 2 presents the summary of prior studies. Section 3 presents the data and methodology. Section 4 presents the estimation outcomes. Section 5 presents the conclusion.

2 Literature review

The stock market is very critical for an economy, and the stock market performance significantly impacts economic activity (e.g., Naik and Padhi 2015). Hence, the interest of numerous scholars is triggered to investigate the stock market development and to conduct empirical studies to find the main determinants and predictors of stock markets, performance. Over the last three decades, numerous studies have extensively investigated the drivers of stock market returns and volatility. For instance, in an influential study, Erb et al. (1995) found that country risk factors (e.g., political) are important factors for forecasting stock returns. Levine and Zervos (1996) suggested that development of stock market could enhance long-term economic growth. Hassan et al. (2003) found that the stock market return volatility is significantly linked with nation risks in the Middle East and African countries. The studies by Caporale et al. (2004) and Naik and Padhi (2015) discussed that well-organized stock markets could rise investment opportunities and promotes economic growth. Chen et al. (2005) found that the rate of unemployment and money supply are significant factors for forecasting stock market returns in Taiwan.

Besides, some studies (e.g., Chau et al. 2014; Mei and Guo 2004; Mnif 2017) argued that domestic political vulnerability is likely to impact stock markets negatively. Cherif and Gazdar (2010) revealed that liquidity of the stock market, saving rate, income level, and interest rate impact development of stock market (SM) in the MENA region. Filis (2010) suggested that the oil prices and the SM impact the consumer price index of Greece positively in the long term while there is no relationship between the stock market and industrial production in the short-term. Lee (2010) discussed that there are two regimes with positive (pre-war) and negative (post-war) relationships between stock return and inflation. Zhao (2010) showed that there is not a stable long-term equilibrium nexus between the Renminbi (RMB) real effective exchange rate and stock price in China. Al-Tamimi et al. (2011) found that the consumer price index impacts companies, stock prices negatively in
the United Arab Emirates (UAE). Büttner and Hayo (2011) also found that size of market capitalization, business cycle synchronization, and interest rate spreads are important elements in explaining stock market integration amongst EU member states.

Furthermore, Hosseini et al. (2011) revealed a short and long-run association between industrial production, crude oil price, supply of money, and inflation rate and stock market index in China and India. Walid et al. (2011) showed that the nexus between foreign exchange markets and stock depend on the regime, and stock price volatility reacts differently to foreign exchange market events. Acaravci et al. (2012) highlighted that there is a long-term relationship between natural gas prices, industrial production, and stock prices. Aliyu (2012) found that the inflation rate significantly impacts stock market volatility in Nigeria and Ghana. Osamwonyi and Evbayiro-Osagie (2012) found that the exchange rates, fiscal deficit, GDP, interest rates, inflation rates, and money supply impact the Nigerian stock market index. The study of Chkili and Nguyen (2014) found that SM has more effect on exchange rates during both calm and turbulent periods. Forson and Janrattanagul (2014) underscored that the industrial production index and consumer price index have a negative long-run link with the Thai stock exchange index. Ko and Lee (2015), by performing the wavelet coherence techniques, revealed that global economic policy uncertainty impacts stock price negatively.

The study of Pradhan et al. (2015) also showed that there is a long-run economic nexus between inflation rate, economic growth, and real effective exchange rate in G-20 countries. Chen et al. (2016) stressed that US economic factors such as industrial production strongly predict the future monthly fluctuations of the stock market in China. Findings of the study by Al-hajj et al. (2017) indicated that the interest rate, the real effective exchange rate, oil price with negative signs, and industrial production with a positive sign impact SM return of Malaysia in the long-run but the inflation has an insignificant effect. Kirikkaleli (2020) found that the amalgamation of foreign risks has a long-term effect on the stock market index in Taiwan. Especially, several studies have been conducted to study the German stock market. Baur and Jung (2006) found there are no spillover effects between the US (DOW) and the German (DAX) stock market indices. Amel-Zadeh (2011) revealed that the marginal effect of firm size on German stock returns depends on the firm’s past performance. Finter et al. (2012) found that investor sentiment explains the return spread between sentiment-sensitive stocks and stocks that are not responsive to sentiment variations. Dimpfl and Kleiman (2019) highlighted that a rise in the pessimism of retail investors is followed by reducing German stock market (DAX) returns. The findings of the study by Miss et al. (2020) do not provide proof of the presence of a Monday effect on the German stock market (DAX).

Despite several studies that have examined the factors of stock market performance and volatility, some studies have mainly focused on investigating the effect of world disease outbreaks and its, related government policy decisions on the developed and developing stock markets. Nippani and Washer (2004) investigated the effect of the SARS outbreak on the stock markets, and the findings showed that SARS adversely impact stock markets in China and Vietnam. Jonung and Roeger (2006) showed that the pandemic which occurred in the EU in 2006 caused a reduction in GDP between 2 and 4 percent. Wang and Thi (2006) found that the contagion effect exists during the Asian flu between the stock markets of Thailand, China, Hong Kong, and Taiwan. Chen et al. (2007) highlighted that the Taiwanese hotel stock prices decline after the SARS outbreak (2003) by 29 percent. Chen, Chen, Tang, and Huang (2009) found that the SARS outbreak (2003) impacts the Taiwanese tourism wholesale and retail sectors, stocks negatively though the biotechnology sector impacts appositively. Besides, Smith et al. (2011) measured the impact of pandemic...
influenza on economic activity in the UK and found that pandemic influenza reduces GDP by 0.3%. Del Giudice and Paltrinieri (2017) showed that the Ebola and the Arab Spring events significantly impact the market returns. Ichev and Marinč (2018) highlighted that the Ebola outbreak events (2014–2016) impacts the financial markets, returns adversely. Remarkably, the study by Zhang et al. (2020) highlighted that the spread of the COVID-19 pandemic impacts financial markets dramatically across countries and creates an extraordinary level of risk and losses for global investors. Al-Awadhi et al. (2020) revealed that transmittable diseases influence stock market returns. Ambros et al. (2020) found there is robust evidence that changes in COVID-19 news rise stock market fluctuations in European countries. Anh and Gan (2020) showed that the increasing daily number of COVID-19 cases adversely impacted Vietnam stock returns and the Vietnam stock market is significantly impacted during the COVID-19 outbreak. Al-Awadhi et al. (2020) revealed that transmittable diseases influence stock market returns. besides, Ashraf (2020b) found that stock markets reacted adversely to the growth in COVID-19 confirmed cases in 43 studied countries, and the stock market returns decreased as the number of confirmed cases raised. In another study, Ashraf (2020c) showed that stock market returns are adversely reacted to a one percent increase in growth in COVID-19 confirmed cases in 43 countries, and particularly its effect is more prominent in the environments with bigger uncertainty aversion culture.

Furthermore, Bai et al. (2020) showed that infectious disease pandemic influences the volatility of global stock markets positively up to a 24-month lag. Bissoondoyal-Bheenick et al. (2020) found that both volatility connectedness and return on the stock rise during the COVID-19 pandemic in the G20 countries. Cepoi (2020) showed that there are asymmetric dependencies between stock markets with the COVID-19 related information (e.g., fake news, media coverage). Erdem (2020) found that the COVID-19 pandemic has a significant negative effect on stock markets of 75 countries so that the volatilities rise and index returns decline. He et al. (2020) found that COVID-19 pandemic has a heterogeneous effect on Chinese industries. Jelilov et al. (2020) showed that the COVID-19 rises volatility of stock market returns. Moreover, Mazur, Dang, and Vega (2021) found that the COVID-19 pandemic differently impacts the stock returns of each sector in the US. The findings of the study by Okorie and Lin (2020) confirmed a fractal contagion effect of the COVID-19 pandemic on the stock markets. Liu et al. (2020) found that the pandemic announcement adversely impacts the global stock market and countries with various income-level react differently to the announcement. Topcu and Gulal (2020) showed that the COVID-19 outbreak has the highest effect in Asian emerging markets while the effect is lower for emerging markets in Europe. Xiong et al. (2020) suggested that the Chinese firms operating in industries that are vulnerable to the virus react more significantly to the COVID-19 outbreak. Also, they found that firm-specific characteristics are matter, and firms with bigger size, more profitability, higher debts, and less tangible assets had a fewer negative effect of the COVID-19 outbreak than other firms. Zhang et al. (2020) showed that global financial market risks have increased significantly by rising the COVID-19 pandemic and causing markets to become highly unpredictable and volatile.

Recently, Aggarwal et al. (2021) revealed that the panic caused by the COVID-19 pandemic impacts the stock return adversely. Corbet et al. (2021) found that the coronavirus pandemic impacts the Chinese financial markets. Its effect is relatively more pronounced than the traditional and long-standing influenza index. Fernandez-Perez et al. (2021)
showed that stock markets have larger decreases and greater volatilities after the first detection in countries having higher uncertainty avoidance and lower individualism culture characteristics. Insaidoo et al. (2021) highlighted that the COVID-19 pandemic impacts Ghana stock returns insignificantly, but stock returns volatility increases by 8.23%. Izzeldin, Muradoglu, Pappas, and Sivaprasad (2021) found that the health care and consumer services sectors in G7 countries are the most severely impacted by the COVID-19 while the technology sector hits the latest and least severely. Narayan, Gong, and Ali Ahmed (2021) concluded that the effect of COVID-19 on the Australian stock market is heterogeneous depending on the type of sector. Uddin, Chowdhury, Anderson, and Chaudhuri (2021) showed that the impact of the COVID-19 pandemic on stock market volatility is lower in countries with higher economic strength. The findings of a study by Xu (2021) showed that there is a negative impact of a rise in the COVID-19 cases on the stock market in Canada and the US. Zhang and Hamori (2021) also found that the effect of COVID-19 creates an extraordinary level of risk and causes relatively higher volatility in the oil and stock markets during the 2008 global financial crisis.

As reviewed, the findings of the majority of studies reveal that the world pandemic outbreaks impact financial markets adversely. In the literature, despite some studies examining the effect of world disease outbreaks on the SM of advanced and developing nations, only some studies have investigated for German stock market. Besides, there is a momentous gap in the related literature to comprehensively examine the pandemic effect under the different regime changes. Therefore, this study fills a gap and contributes to the literature by testing the effect of the world pandemic uncertainty index on the DAX index, for the 1996Q1 to 2020Q3 period while controlling real effective exchange rate, industrial production index, and consumer price index. Furthermore, this study contributes significantly by employing advanced approaches including the Fourier ADF Unit Root, Fourier Engle-Granger Cointegration, Bayer-Hanck Cointegration, and Markov switching regression tests, which makes this study to be significant and also open a new discussion in the related literature.

3 Data and methodology

This research aims to examine the impact of the world pandemic uncertainty index on the DAX index, for the 1996Q1 to 2020Q3 period while controlling the industrial production index, real effective exchange rate, and consumer price index. This study was used the world pandemic uncertainty index data as constructed by Ahir et al. (2021). Besides, the German stock market index data was collected from the Worldscope database. Moreover, this study was collected the data for the controlling variables from International Monetary Fund (IMF).

The model with the control variable is depicted in Eq. (1):

\[ STOCK_t = \alpha_0 + \alpha_1 PAN_t + \alpha_2 REER_t + \alpha_3 IIP_t + \alpha_4 CPI_t + \epsilon_t \]

where \( STOCK_t \) is the German stock market index, \( PAN_t \) is the world pandemic uncertainty index, \( REER_t \) is the real effective exchange rate, \( IIP_t \) is the industrial production index, and

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2 See studies by Athari et al. (2021), Irani et al. (2021), Kirikkaleli et al. (2021).
3 https://worlduncertaintyindex.com/data/.
$CPI_t$ is the consumer price index. The variable was transformed into their natural logarithm. These variables $CPI_t$, $IIP_t$ and $REER_t$ are the control variables for our model. In addition, $\varepsilon_t$ is the residual term while $\alpha_{1-4}$ are elasticity coefficients in the equations.

The order of integration is usually the first step undertaken in any study determined to achieve a similar purpose. This study employed the Augmented Dickey–Fuller (ADF) and Fourier ADF unit root tests. The ADF unit root as is defined as follows in Eq. (2):

$$
\Delta B_t = \varphi \dot{C}_t + \beta_1 B_{t-1} + \sum_{i=1}^{n} b_i \Delta Y_{t-1} + \varepsilon_t
$$

(2)

where $\dot{C}_t$ denotes the deterministic components, which detect causal factor and $B_t$ denotes the series used, $\Delta$ denotes the first difference.

ADF unit root is not capable to detect structural changes but the Fourier ADF Unit Root solves the weakness of the ADF unit roots test. This Fourier approach provides information about the number of structural changes, form, and date. Therefore, Enders and Lee incorporated the Fourier approximation approach into the framework of the ADF, which the deterministic components are defined as:

$$
\sigma(t) = \sigma_0 + \sum_{i=1}^{n} \gamma_1 \sin \left( \frac{2\pi kt}{T} \right) + \sum_{i=1}^{n} \gamma_2 \cos \left( \frac{2\pi kt}{T} \right); n \leq \frac{T}{2}
$$

(3)

where: n, k and T denote the numbers of frequency, frequency and number of observations respectively.

Cointegration association for the model (1) and (2) was assessed using the Bayer and Hanck cointegration, which a combined test initiated by Bayer and Hanck (2013). It merges cointegration tests such as Engle and Granger (1987), Boswijk (1994), Johansen (1991), and Banerjee et al (1998). This cointegration test employed the fisher formula, which is explained in Eqs. (4) and (5):

$$
EG - JOH = -2[\ln(PEG) + \ln(PJOH)]
$$

(4)

$$
EG - JOH - BO - BDM = -2[\ln(PEG) + \ln(PJOH) + \ln(PBO)\ln(PBDM)]
$$

(5)

where: PEG, PJOH, PBO, and PBDM are the level of significance Engle and Granger (1987), Johansen (1991), Boswijk (1994), and Banerjee et al (1998), correspondingly. Furthermore, this study employed the Fourier Engle-Granger Cointegration test as a robustness test for the Bayer and Hanck cointegration.

Furthermore, the study employed the Markov switching regression. This technique gives superior results compared with other econometric time series techniques, in particular whenever the variance of a series and non-linear dynamics suddenly changes (Hamilton 1989). This approach has the greatest benefit when it comes to the flexibility of models due to regime changes. Saltoglu et al. (2003) stressed that the method can be used in complex, linear, and non-stationary cointegrated models. It is assumed that the effect of the regressors on the dependent variable can be expressed in two regimes.
4 Empirical results and discussion

The present study aims to assess the effect of the world pandemic uncertainty index on the German stock market index for the 1996Q1 to 2020Q3 period while controlling the real effective exchange rate, industrial production index, and consumer price index. The descriptive statistics of the considered variables are summarised in Table 1. As presented, the mean value for STOCK is 7069.233; for CPI is 97.28220; for IIP is 98.40093; for PAN is 12.29646, and for REER is 101.8830. Table 1 shows the minimum and maximum values for STOCK ranges from 2479.177 to 13117.39, CPI from 81.34011 to 113.9003, IIP from 74.15508 to 116.3835, PAN from 0.000000 to 416.3500, and REER from 91.45439 to 119.3451. Regarding the skewness of this series, the distribution of PAN is highly skewed, but the distribution of STOCK is skewed moderately while the skewness of CPI, IIP, and REER is symmetric. However, the series distribution with Kurtosis indicates STOCK, CPI, IIP, and REER are platykurtic while PAN is leptokurtic. According to the Jarque–Bera and its P-value, all series are not normally distributed except REER.

For a cointegration test to be explored, the integrated order of the series ought to be known. This study employed the ADF and Fourier ADF unit root to establish the integration order of these series, which outcomes at the level and first difference were depicted in Table 2. For the ADF unit root, the outcome reveals that all series are integrated at I(1), indicating similar integration order. Similar integration order was also confirmed in the Fourier ADF unit root, where all series at I(1). At a 5% significance level, the null hypothesis was rejected by the ADF and Fourier ADF unit root.

Since the integration order is established, the cointegration test can be explored. This study undertakes the cointegration test using the Bayer and Hanck (2013) cointegration approach, a combined cointegration test. The outcome of the Bayer and Hanck (2013) cointegration approach was described in Table 3. It is evident that cointegration is present since the null hypothesis is rejected at a 5% significant level when the computed F-statistics is higher than its critical value. Furthermore, this study also employed the Fourier

| Table 1 Descriptive statistics |
|--------------------------------|
| German stock market index (STOCK) | Consumer price index (CPI) | Industrial production index (IIP) | World pandemic uncertainty index (PAN) | Real effective exchange rate (REER) |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Mean 7069.233 97.28220 98.40093 12.29646 101.8830 |
| Median 6277.777 98.57488 100.2090 1.160000 100.0272 |
| Maximum 13,117.39 113.9003 116.3835 416.3500 119.3451 |
| Minimum 2479.177 81.34011 74.15508 0.000000 91.45439 |
| Std. dev 3032.070 10.01728 11.24686 56.15666 6.160206 |
| Skewness 0.508780 0.020887 -0.297588 6.289797 0.466189 |
| Kurtosis 2.109665 1.667691 1.888421 42.29642 2.590777 |
| Jarque–Bera 7.541018 7.329270 6.558099 7022.626 4.276762 |
| Probability 0.023040 0.025614 0.037664 0.000000 0.117845 |
| Sum 699,854.1 9630.938 9741.692 1217.350 10,086.42 |
| Sum sq. dev 9.01E + 08 9833.902 12,396.20 309,049.9 3718.917 |
| Observations 99 99 99 99 99 |

Table 1 shows the descriptive summary of using variables
Engle-Granger cointegration test as a robustness check for the Bayer and Hanck cointegration test outcome. The outcome of the Fourier Engle-Granger cointegration test agrees with the outcome of the Bayer and Hanck cointegration test. Since the null hypothesis was rejected at a 5% significant level, there is a cointegration association between the dependent variable (STOCK) and its independent variables (CPI, IIP, PAN, and REER).
By establishing the cointegration, the impact of the world pandemic uncertainty index on the German stock market index was examined for the different regimes by using the Markov switching regression approach while controlling the real effective exchange rate, industrial production index, and consumer price index factors. This study investigates the German stock market index at two different regimes, namely the low variance regime and the high variance regime. Table 4 summarizes the outcome of the Markov switching regression.

| Variable | Coefficient | Std. error | z-statistic | Prob  |
|----------|-------------|------------|-------------|-------|
| Panel A: Regime 1                      |             |            |             |       |
| Low volatility regime                  |             |            |             |       |
| REER    | −153.094*   | 33.266     | −4.602      | 0.000  |
| IIP     | 41.843      | 27.994     | 1.494       | 0.135  |
| CPI     | 177.7340*   | 32.030     | 5.548       | 0.000  |
| PAN     | −357.839*   | 88.064     | −4.063      | 0.000  |
| C       | 3212.772    | 5210.241   | 0.616       | 0.537  |
| Panel B: Regime 2                      |             |            |             |       |
| High volatility regime                 |             |            |             |       |
| REER    | −157.353*   | 52.508     | −2.996      | 0.002  |
| IIP     | 84.6425**   | 36.758     | 2.302       | 0.021  |
| CPI     | 139.884**   | 60.421     | 2.315       | 0.020  |
| PAN     | −9.5164*    | 3.545      | −2.683      | 0.007  |
| C       | 166.080     | 8715.674   | 0.019       | 0.984  |

1% and 5%, significance level are represented by * and ** respectively

In Regime 1 and Regime 2, the real effective exchange rate negatively impacts the German stock market index, signifying that the real effective exchange rate does not improve the German stock market index. This finding agrees with the study of Al-hajj et al. (2017). The finding supports the flow-oriented model, which underlines the importance of exchange rate movement for determining the pattern of stock market movements. The model suggests that "the currency exchange will impact the international competitiveness and trade balances, thereby affecting the countries, outputs, and therefore influencing stock prices" (Sui and Sun 2016). Besides, the industrial production index in the low variance regime has a positive and non-significant coefficient, but in regime 2, a positive and significant coefficient was discovered. Since the industrial production index is one of the important proxies for economic growth, we can conclude that this outcome supports the demand-leading hypothesis, which underlines financial development responds to changes in the real sector. Therefore, accelerating economic growth in Germany is associated with accelerating the application of stock prices. For the consumer price index in Regime 1 and Regime 2, it was detected that there is a positive and significant coefficient, showing consumer price index contributes to the German stock market index. Finally, the world pandemic uncertainty index has a negative and significant coefficient on the German stock market index. This indicates that the global pandemic has had a detrimental effect on the German stock market index. This outcome is consistent with the study of Aggarwal et al. (2021), Uddin et al. (2021), and
Xu (2021). The investors in the DAX market should prepare themselves against pandemic uncertainty in today’s world. The first wave of the COVID-19 also showed how global health uncertainty could be an important predictor for stock market indexes in the world.

5 Conclusion

The COVID-19 effect on a nation’s economy and financial markets have been one of the most heavily investigated concepts in the literature since the beginning of 2020 (Ashraf 2020b; Narayan et al. 2020; Phan and Narayan 2020; Ramelli and Wagner 2020) and the studies generally underlined the negative effect of COVID-19 on stock market performances. The existing empirical studies only focus on the short period and use mostly correlation analysis or pattern analysis. To create a new discourse about the influence of the world pandemic on the German stock market index (DAX), the present study used a relatively long dataset from 1996Q1 to 2020Q3 while controlling real effective exchange rate, industrial production index, and consumer price index. The present study used newly developed and novel econometrics techniques, namely Fourier ADF Unit Root, Fourier Engle-Granger Cointegration, Bayer-Hanck Cointegration, and Markov switching regression tests. The outcomes of the study reveal that the German stock market index is negatively influenced by the world pandemic uncertainty index over the selected period, implying that rising pandemic uncertainty is associated with declining stock prices in Germany. This finding suggests that the investors in the DAX market should prepare themselves against pandemic uncertainty in today’s world. The first wave of the COVID-19 also showed how global health uncertainty could be an important predictor for stock market indexes in the world. The outcome of this study also reveals that while the consumer price index and industrial production index have a positive impact on the DAX market, exchange rate depreciation (appreciation) affects the DAX market negatively (positively).

The outcomes have vital consequences for policymakers and investors. First, it suggests to policymakers by enhancing the economic growth in Germany could make the better functioning and efficiency of stock market. Second, it recommends to domestic and global investors in the DAX market prepare themselves by diversifying their portfolios against the exchange rate depreciations and pandemic uncertainty to maintain the expected return-risk tradeoff. Although the present research makes it possible to identify strong empirical findings regarding the pandemic and German stock market association, further studies should be conducted using similar methodologies for other developed countries to examine whether the COVID-19 impact differs

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Availability of data and material  The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest  The authors have no relevant financial or non-financial interests to disclose.
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