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A vaccine for volatility? An empirical analysis of global stock markets and the impact of the COVID-19 vaccine

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ABSTRACT

The oscillation of COVID-19 growth has had a sustaining impact on financial markets. This study investigates the asymmetric impact of COVID-19 growth and recovery on financial markets. Examining ten epicenters of the virus from 01/01/2021 to 31/12/2021, we utilize a stepwise regression methodology and a diverse set of control variables. Controlling for volatility, credit risk, liquidity risk, monetary policy, gold, and oil, our findings indicate a significant impact of COVID-19 on equity indices. Vaccination growth correlates with positive price movements in the USA, UK, China, Japan, France, and Spain. Simultaneously, negative price trends align with virus growth in the USA, UK, China, Japan, Spain, and World models. A nexus of causality between COVID-19, global oil markets, and equity prices is identified, while credit and liquidity risks emerged as significant risk factors in China. Our results highlight the pertinence of swift vaccine developments, lockdown interventions, and central bank responses, providing valuable insights to governments, regulators, and all financial market stakeholders.

1. Introduction

As global COVID-19 vaccination programs gathered pace throughout 2022, fears of repeated restrictions on travel and commerce began to fade. With this, governments, policymakers, and regulators have now begun to take stock of the financial and economic damage incurred as societal and economic recoveries come into key focus. The recent pandemic and subsequent ramifications for all aspects of society have presented several research areas propitious for examination. As the pandemic first took hold in 2020, the immediate impact on financial markets was observed by academia and stock market practitioners alike. The Dow Jones and the S&P 500 experienced their worst trading days since Black Monday of 1987 (Stevens et al., 2020), with Gandel (2020) reporting over $16 trillion in stock market losses in March 2020 alone. Several immediate studies undertaken in the early months of the pandemic examined this initial reaction of stock markets and the initial fear response of investors. Ashraf (2020) and Al-Awadhi et al. (2020) used panel data to illustrate the significant adverse reaction of international stock markets to confirmed cases of COVID-19. Similarly, Ali et al. (2020) used a bivariate regression analysis to examine stock market returns and their negative association with COVID-19 deaths. Overall, in the early months of 2020, the literature observed that financial markets worldwide saw a significant increase in volatility, directly attributable to COVID-19 (Zhang et al., 2020). This study aims to examine the impact of negative COVID-19 sentiment and associated growth (total cases) and positive COVID-19 sentiment and recovery (total vaccinations) on financial markets during the later stages of the pandemic.

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The motivation behind this analysis is to contribute and fill an existing gap in the literature on COVID-19 cases and vaccination data, and financial market performance. Building on the current research discussed in Section 2, we not only test the relationship between COVID-19 and financial markets but also control for a robust set of market factors. These include volatility, credit risk, liquidity risk, monetary policy, safe-haven asset demand, and the price of oil. Building upon previous studies, this analysis examines the substantial wave of the pandemic in 2021, providing insights into the relationship between COVID-19 and stock markets during the critical introduction of vaccine programs. By conducting a country-by-country analysis, this research identifies the individual impact of COVID-19 data on each respective stock market. It explores asymmetries between developed and emerging markets in their responses to COVID-19 cases and vaccinations, shedding light on stock market drivers specific to each country in times of crisis.

We analyze data from January 2021 to June 2021, thus analyzing the immediate reaction of financial markets in the wake of the rollout of global vaccination programs. While the remit of this analysis is to focus extensively on the initial impact of vaccinations during the first six months of 2021, we also include an additional analysis in Section 5 covering the following six months, from July 2021 to December 2021. With this, we also identify changes in the dynamics of financial market drivers in the ever-evolving macroeconomic environment as the prevalence of COVID-19-related shocks diminished, and new risk factors emerged. The regions examined are China, Japan, the United Kingdom, Italy, Spain, Germany, France, the United States, and India, and a global measure of pandemic and financial market growth. These were chosen due to the manifestation of pandemic epicenters in these regions as the virus grew, first originating in China and establishing sequential and dominant epicenters in each area analyzed as the pandemic took hold in 2020 and grew into a global crisis.

Our empirical results confirm that equity index prices suffered a significant negative shock in line with the sustaining growth of the virus even as vaccine programs began. Namely, for China, Japan, the UK, Spain, and World models. It is also found that equity index prices responded positively to growth in total vaccinations, with statistical significance observed for China, Japan, the UK, Spain, France, and the USA. Developed countries with strong vaccination approval and uptake levels observed a positive association with equity index prices. However, India, an emerging market with high levels of vaccine hesitancy and low vaccine administration, did not observe a similar reaction. In line with the current body of literature, the implied volatility of each respective index was a driving force in equity index prices. Additionally, the price of oil was, on average, positively associated with equity index prices in the first half of 2021 before reversing to a negative relationship in the latter six months. This occurred as inflation fears, rising fuel prices, and geopolitical tensions rose. Finally, our findings illustrate the susceptibility of Chinese stock markets to concerns about credit and liquidity risks, in line with deteriorating credit conditions observed in the market over this analysis period.

The study proceeds as follows. Section 2 explores the current literature on this research topic and the contributions of this study. Section 3 describes the data and empirical methodology used in the investigation. Section 4 outlines the results, while Section 5 explores and discusses the implications of these results in the context of the current financial and economic landscape. Section 6 concludes the analysis.

2. Literature review

The body of pandemic-related literature has grown significantly since COVID-19 emerged, with studies now considering extended time-frames of the outbreak and more granular aspects of the market dynamics that were at play. With this emergence of literature, several directions for future research in the intersection between COVID-19 and financial markets are explored. Boubaker et al. (2023) finds that investor sentiment, stock market reactions to COVID-19, oil prices, safe haven assets, and the interconnectedness between cryptocurrencies and traditional assets all featured heavily in both 2021 and 2022. O'Donnell et al. (2021) examined the complete first wave of the virus, from January to June 2020, controlling for several of these market drivers. These findings indicated a significant negative relationship between major international stock markets and COVID-19 cases. Notably, these findings were not observed for China. Findings from (Liu et al., 2022) echo these results, whereby fear sentiment alone led to a direct fall in stock prices, with panic exacerbating this negative impact. O'Donnell et al. (2021) confirm that investor sentiment impacted market prices before any visible financial damage was incurred as the pandemic took hold. Similarly, controlling for country-specific characteristics, expected future economic losses, and systematic risk due to international factors, a similar adverse reaction of markets to COVID-19 was found by (Ashraf, 2021). These findings differed country by country, depending on each country's uncertainty aversion index. Countries with high levels of uncertainty aversion experienced significantly higher negative market returns during the pandemic period. Similarly, Ho et al. (2023) investigate modern pandemic crises and default risk. Examining SARS (2003), H1N1 (2009), MERS (2012), Ebola (2014), and Zika (2016), the authors find a significant increase in the default risk of enterprises. However, this impact was dependent on the timely adoption of International Financial Reporting Standards and the political stability of each region.

Among other asset classes, similar results are present. Cicchiello et al. (2022) investigated the impact of the pandemic on green bonds, finding a wide expansion of credit spreads as the pandemic took hold. However, as vaccine developments emerged and pandemic fears eased, these spreads fell below those of conventional bonds, thus indicating a higher risk exposure to downturns but ultimately higher upside exposure in recovery times. Within alternative investments, Al-Nassar et al. (2022) uncover a time-varying hedging role of gold, oil, and Bitcoin throughout the pandemic, indicating a promising hedging role for all three investments in times of crisis.

The global and homogenous response of stock markets to COVID-19 has also spurred several studies examining interconnectedness and spill-over effects between financial markets in times of distress. Karamti and Belhassine (2021) used a wavelet coherence analysis, Abuzayed et al. (2021) used conditional value-at-risk (CoVaR) and GARCH models, and Youssef et al. (2021) used time-varying VaR models to investigate the COVID-19 pandemic. These findings identified highly connected financial markets during the COVID-19 pandemic, uncovering a significant spill-over of negative returns across markets. Notably, this spill-over effect emerged primarily

from fear, uncertainty, and evolving investor sentiment surrounding developments in the pandemic, in line with previous studies (Ashraf & Goodell, 2022; Ashraf, 2021; Liu et al., 2022; O'Donnell et al., 2021). El Khoury et al. (2023) examine spillovers and risk transmission in the context of the Russia-Ukraine war, highlighting the importance and hedging potential of the ESG, FinTech, and renewable energy sectors in the post-COVID-19 macroenvironment. It was found that FinTech and ESG were net transmitters in developed countries, while Gold and renewable energy were net receivers in the pre-war and war periods. The hedging effectiveness of Gold and ESG sectors was observed during times of crisis.

The emerging literature has also investigated the manifestation of asymmetric impacts of COVID-19. Maghyere et al. (2022) studied the asymmetric transmission of risk in the U.S., Japan, Canada, Germany, and the U.K. Findings here reveal a persistent and uniform asymmetry in information transmission, whereby the spillover of 'bad' volatility is higher than the spillover of 'good' volatility. Results suggest that the U.S. market remains the critical global market in transmitting risk to other financial markets. This aligns with Li et al. (2021), who find that developed markets are the main spillover transmitters, with emerging markets acting as the leading spillover receivers of volatility shocks.

In contrast, Vuong et al. (2022) include China in their analysis, the global origin of the virus. Rather than originating from the U.S. stock market, an asymmetric transmission of volatility spillovers from China to the U.S. stock market was observed when COVID-19 first broke out. Including Sukuks and Islamic financial products, Arfaoui et al. (2022) observed a similar asymmetric spillover of shocks to U.S. stock markets during the COVID-19 period. The above literature indicates an inextricable and asymmetric bilateral linkage between global financial markets in times of widespread macroeconomic stress.

While the current research has focused extensively on whether COVID-19 was significant or not in negatively impacting stock markets, Figs. 1 and 2, and Table 1 illustrate that while COVID-19 continued to grow throughout 2021, major global indices recovered significantly towards their pre-pandemic prices from December 31st, 2019. This raises the critical question of how major stock markets, described by Pradhan et al. (2013) as 'catalysts of economic growth,' recovered before the virus had fully abated and before societal and commercial lockdowns had been fully lifted. Despite prolonged closures in vital sectors such as hospitality and tourism, broader stock market indices not only rebounded but also sustained growth. While the direction of causality between economic growth and stock markets is strongly contested, Niewerburgh et al. (2006) argue it is conceivable that causality proceeds in both directions simultaneously, whereby stock markets are a leading indicator of economic activity and vice versa. Given this, this phase of the pandemic now requires an investigation into the significance of COVID-19 and the drivers of stock markets during a time when economic projections were so pessimistic (IMF, 2020a).

Limited studies are available in the area of stock market performance and vaccinations, a significantly positive indicator of pandemic recovery and economic growth during the COVID-19 crisis. Rouatbi et al. (2021) examine the impact of vaccine programs on global stock market activity, finding a stabilization of global equity markets. However, this was felt asymmetrically in markets, whereby developed markets were impacted more strongly than emerging ones. Similarly, Chan et al. (2022) reveal a strong positive reaction in global markets to the onset of clinical trials for COVID-19 vaccines. This was observed more strongly for U.S. and Chinese vaccine program developments. Outside of vaccine developments, the impact of social-distancing measures as both a negative and

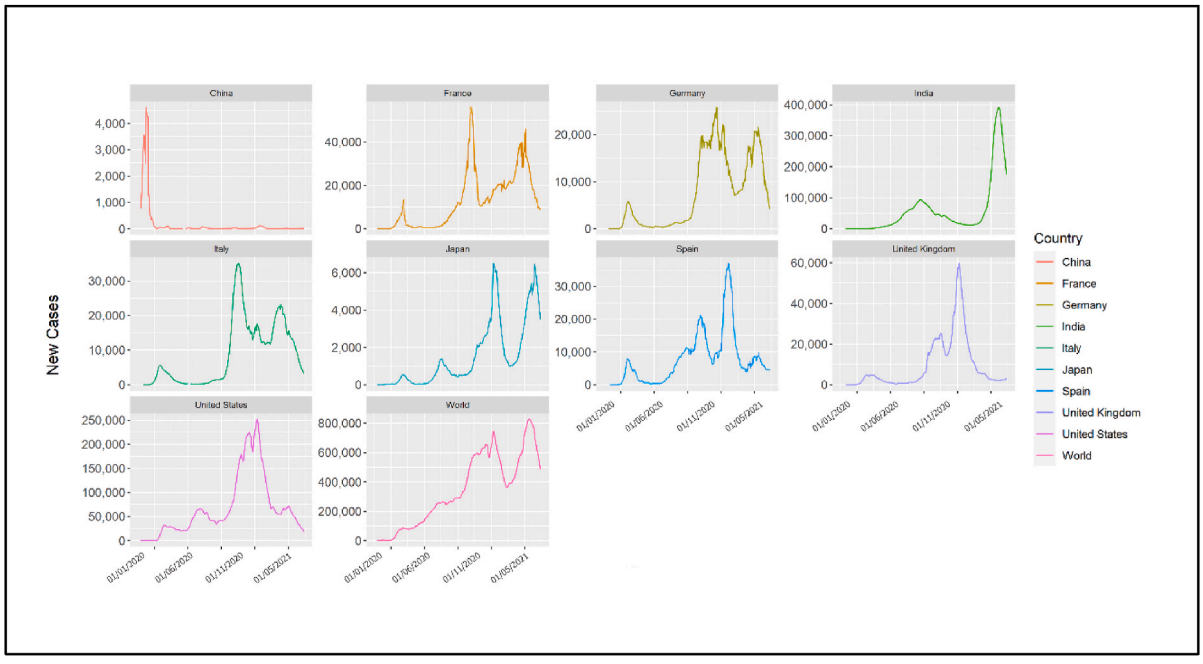

Fig. 1. Illustrates the growth of new cases of COVID-19 in each of the ten regions examined from December 2019 to June 2021. The outbreak in 2021 vastly exceeds the magnitude of the initial outbreak observed in 2020.

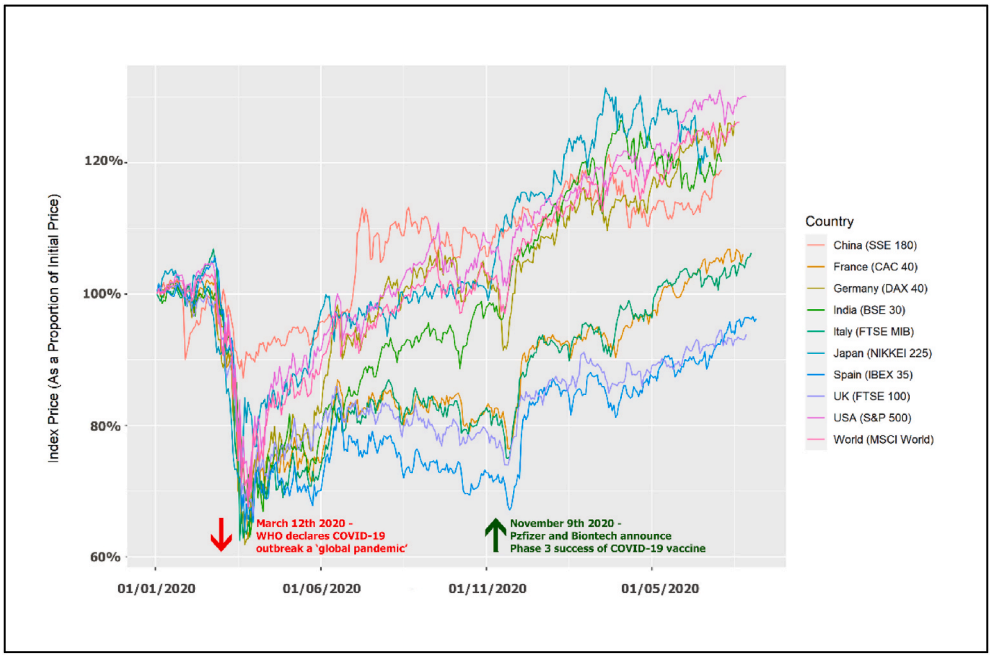

Fig. 2. Illustrates the price action of the ten major equity indices included in this analysis, from December 2019 to June 2021, from the initial COVID-19 shock to the subsequent recovery.

Table 1
The ten equity indices used in this analysis and the current percentage of their pre-pandemic price as of June 30th' 2021, relative to December 31st' 2019. Each index has recovered significantly throughout the pandemic.

Country		Equity Index	Percentage of Pre-Pandemic Price
	China	SSE 180	**118% (+18%)**
	Japan	NIKKEI 225	**119% (+19%)**
	U.K.	FTSE 100	**94% (-6%)**
	Italy	FTSE MIB	**106% (+6%)**
	Spain	IBEX 35	**96% (-4%)**
	Germany	DAX 40	**116% (+16%)**
	France	CAC 40	**107% (+7%)**
	U.S.A.	S&P 500	**130% (+30%)**
	India	BSE Sensex	**120% (+20%)**
	World	MSCI World Index	**126% (+26%)**

positive driver of stock markets was investigated by Ashraf and Goodell (2022). While social distancing policies reduced economic growth in the current quarter under analysis, they increased economic growth in the next, indicating a simultaneous short-run adverse effect and long-run recovery effect.

This study contributes to the above literature in several ways. Firstly, to expand and advance the limited literature on the impact of COVID-19 vaccines (Rouatbi et al., 2021; Chan et al., 2022; Cevik et al., 2022), this study incorporates COVID-19 vaccination data from both developed and emerging markets. Several studies published thus far have focused only on the negative significance of COVID-19 cases or fatalities (Al-Awadhi et al., 2020; Ali et al., 2020; Ashraf, 2020; Choi & Jung, 2021; Chowdhury et al., 2022; Sansa, 2020; Scherf et al., 2022; Xu, 2021). The administration of COVID-19 vaccinations in each of the ten aforementioned regions is therefore included in this study as a proxy of pandemic recovery and growing positive sentiment. Alongside this, COVID-19 cases, a proxy of pandemic growth, will also be included to uncover whether a growing negative sentiment indicator remains significant amid substantial developments in pandemic recovery. A robust set of market factors, including volatility, credit risk, liquidity risk, monetary policy, safe-haven asset demand, and the price of oil, are included to identify whether traditional market drivers can be used to explain global equity prices or whether COVID-19-related data continues to impact financial markets. As such, we investigate whether a

'positive' COVID-19 variable (total vaccinations) prevails as a significant factor in a stock market model in the presence of our 'negative' COVID-19 variable (total cases) and an additional dataset of traditional stock market drivers as controls.

Secondly, there is a large body of literature that examines the initial and short-term impact of COVID-19 on stock markets since the pandemic emerged in early 2020 (Ali et al., 2021; Ambros et al., 2021; Ashraf, 2020; Zeren and Hizarci, 2020; Ramelli & Wagner, 2020; Liu et al., 2020; O'Donnell et al., 2021). This analysis adds to this literature by examining the substantial pandemic wave between January 2021 and December 2021. This paper builds on previous studies, providing important insights into the development of COVID-19 and financial markets throughout 2021 during the critical introduction of vaccine programs in the first half of 2021.

Finally, we contribute to the current literature by conducting a country-by-country level analysis of COVID-19 and international stock markets. We employ a country-specific stepwise regression model for each region to identify the individual rather than the collective impact of COVID-19 data in each respective stock market. As such, we can utilize regional-specific financial market variables in each market as proxies for volatility, credit risk, liquidity risk, monetary policy, safe-haven asset demand, and oil. Additionally, by analyzing the differences in stock market drivers in ten country-specific models, we can identify and uncover asymmetries between developed and emerging markets in their response to both the growth in COVID-19 cases and COVID-19 vaccinations. Given this, the following research will also add to the aforementioned body of literature on the asymmetric interconnectedness of financial markets in times of crisis.

3. Data and methodology

3.1. Data collection and standardization

Daily data for this analysis was gathered for both COVID-19 growth and financial market growth from 01/01/2021 to 30/06/2021 and from 01/07/2021 to 31/12/2021. Daily data of cumulative confirmed cases of the virus was sourced from John Hopkins University (2022). Daily cumulative vaccination data was sourced from the most recent official figures released by various health ministries, a dataset compiled and managed by Our World in Data (2022). Cumulative data of COVID-19 was chosen as the proxy for pandemic growth in line with the current body of literature emerging on the subject, with recent studies including Al-Awadhi et al. (2020), Ashraf (2020) and Del Lo et al. (2021) all utilizing confirmed cases of COVID-19 in their respective analyses of COVID-19. Preliminary testing of raw COVID-19 data reveals a distinct correlation between total cases with index prices, more so than total death figures, as per O'Donnell et al. (2021). This aligns with previous studies utilizing this indicator as their COVID-19 variable. Therefore, the other COVID-19 growth variables are disregarded since they are either highly correlated with total cases or uncorrelated with index prices.

Furthermore, while the calculation of COVID-19 cases is transparent through testing, Riley et al. (2021) highlight a significant disparity in the calculation and reporting of deaths and associated mortality rates, making such measures and reported levels inconsistent across regions. A considerable time lag between cases and deaths is also reported by Jin (2021). While case rates increased throughout the pandemic, death rates remained low in many areas. After several weeks, death rates subsequently increased by varying amounts. Given this and this study's daily scope, COVID-19 case numbers were chosen as the appropriate measure of COVID-19 growth. Bhaskaran et al. (2021) also find that mortality from COVID-19 shows a strong relationship with age and pre-existing medical conditions, while factors related to COVID-19 infection were relatively indiscriminate. Therefore, while mortality rates indicate a crisis of public health, case numbers are more representative of the overall spread of the virus among the masses, prompting additional governmental measures and lockdowns more likely to cause economic disruption to financial markets. Total Cases and Total Vaccinations were then standardized to cases and vaccinations per million due to the significant differences in populations across the regions examined.

The targeted focus on the first six months of 2021 is rationalized and in line with the vaccination developments outlined in Tregoning et al. (2021). By early May, the USA announced its support for waiving COVID-19 vaccine patents. As of June 14th, 2021, vaccines from nine providers had been approved for rollout to adults and, in some cases, to adolescents, with over 2.8 billion vaccine doses administered worldwide. In parallel, international travel began to resume to normality in Europe with the introduction of the EU Digital COVID Certificate (Europa, 2021). Thus, in order to examine the immediate impact of these positive pandemic developments on financial markets, the period encompassing the first six months of 2021 effectively captures this initial period of positive pandemic sentiment in financial markets. This is in parallel with similar studies which emerged at the beginning of the pandemic, analyzing the immediate impact of COVID-19 cases and fatalities on financial markets using a similar time frame (Al-Awadhi et al., 2020; Ashraf 2020, 2021; Zhang et al., 2020). As shown in Figs. 1 and 2, along with Tables 1, it is evident that despite the ongoing growth of COVID-19 throughout 2021, prominent global indices exhibited substantial recovery, approaching their prices from before the pandemic, specifically those on December 31st, 2019.

Extending O'Donnell et al. (2021), additional regions are examined in this study to account for both emerging and developed markets affected by COVID-19. These regions are China, Japan, the UK, Italy, Spain, Germany, France, the USA, and India, and a measure of the global impact of COVID-19. The equity indices associated with these regions are outlined above in Table 1. Closing equity index prices were obtained using a Bloomberg terminal for the same date range. To align trading days to calendar dates of COVID-19 data, the dataset was filtered for business days, with any missing data points backfilled with the previous reported day's data. This ensured a smooth and temporal dataset that captured the cumulative progression of COVID-19 data in line with financial market trading days. COVID-19 data was then lagged one day behind index prices for the purpose of our stepwise regression analysis. COVID data from one day prior was used to measure against the prevailing day's index price. This accommodated the human sentimentality of trading, whereby trading on day (T_0) may be based on the most up-to-date data released on day (T_{-1}).

Several sources available in the public domain were used to gather the explanatory and control variables detailed in Section 3.2. Yahoo Finance was used to collect the Volatility Index and Commodity (Gold and Oil) prices. A Bloomberg Terminal was used to collect measurements of credit and liquidity risk (LIBOR-OIS Spread and TED Spread) alongside the Federal Reserve Economic Database (FRED), European Central Bank (ECB), Bank of England (BOE) and China Central Depository & Clearing (CCDC) for the regions in the scope of this study. All the above data, including the COVID-19 data was downloaded, cleaned, and collated into country-by-country datasets in Python, the source code of which is available alongside this paper on GitHub (2022).

3.2. Variable selection

This study aims to examine the impact of COVID-19 growth (through case numbers) and COVID-19 recovery (through vaccinations) on the performance of stock market indices while controlling for several market drivers. Haldane and Chowla (2021) highlighted the importance and utility of 'fast indicators' when tracking economic performance in the face of an unforeseen crisis, such as that precipitated by COVID-19. Using typical economic indicators such as GDP or unemployment data can present challenges due to the significant lag between their official release and the period under analysis. It is, therefore, more appropriate and significantly more insightful to use a live dataset that can offer real-time insight into how the economy is performing day-on-day (Aaronson et al., 2020; Carvalho, Hansen, & Ortiz, 2021). As such, with a fast-moving and evolving situation such as that presented by the recent pandemic, we chose a selection of daily economic and financial indicators. This temporal and continuous dataset allowed us to capture the daily changes in financial market dynamics and effectively control for investor sentiment, safe-haven asset demand, credit risk, liquidity risk, monetary policy, and the price of oil on a day-by-day basis as the COVID-19 pandemic evolved.

In addition to the two COVID-19 variables (cases and vaccinations), five additional variables per region were chosen to explain equity index prices. Each variable per region differs slightly due to the regional nature of each financial product and the rate available. However, each of the five variables effectively captures the same controlling risk factor in each region. As such, the same seven variables are considered for each region in this analysis to effectively examine the significance of each risk factor on financial markets. Table 2 below briefly outlines and defines the control variables used in this analysis. The following paragraphs expand on Table 2, detailing and justifying their utility in this stock market analysis.

3.2.1. Volatility Index

Volatility indices represent the 30-day forward expectation of volatility in financial markets. Rosillo et al. (2014) showcase the significant explanatory power of such indices in predictive stock market algorithms, while Poshakwale et al. (2019) have shown a significant link between volatility indices and market returns, especially in bearish periods. Karamti and Belhassine (2021) identified 'fear' as leading equity markets throughout COVID-19. Therefore, this variable's inclusion is warranted in this analysis as an ex-post measure of market activity and a proxy for the current 'fear' or sentiment of investors.

3.2.2. LIBOR-OIS spread

An overnight indexed swap (OIS) rate is the forward-looking benchmark of the central bank's target rate and provides insight into the unsecured borrowing rates among banking institutions to meet liquidity needs. The probability of counterparty risks occurring overnight between these institutions is low, so the OIS rate can typically be considered a near-riskless rate (Sengupta & Tam, 2008). The LIBOR rate, on the other hand, is the daily rate used on unsecured borrows between banking institutions to fund operations.

Unlike the OIS rate, LIBOR is affected by credit and liquidity risk. Therefore, LIBOR and OIS rates tend to diverge during economic stress. Both Brunnermeier (2009) and Sarkar (2009) identified a significant divergence in this spread due to the housing crisis and global financial crisis in 2008. In 2020, despite banks not being the epicenter of the COVID-19 liquidity squeeze, Eren et al. (2020) found liquidity outflow from money-market-funds precipitated sharp spikes in the LIBOR-OIS spread as the crisis unfolded. Given this, we use the LIBOR-OIS spread as a control for deteriorating credit and liquidity conditions in financial markets.

Table 2
Summary information on the five market forces controlled for in this analysis, collectively covering investor sentiment, volatility, credit risk, liquidity risk, economic risk, safe-haven asset demand, and global oil markets.

Market Force:	Controlling Instrument:	What it Measures:
Volatility	*Volatility Index*	*An index measuring the implied volatility of its respective equity index derived from the price inputs of forward-looking options.*
Liquidity Risk and Monetary Policy	*LIBOR-OIS Spread*	*The spread between the 1M LIBOR rate and the Overnight Indexed Swap rate, indicating the perceived fear of liquidity and credit risks in the banking sector*
Credit Risk and Monetary Policy	*TED Spread*	*The spread between the yield on a 3M government bond and the 3M LIBOR rate, indicating the perceived 'price' of money in the global banking system, and the perceived level of credit and overall economic risk on the broader economy.*
Safe Haven Assets	*Gold Commodity Price*	*The price of gold and the current market demand for this commodity, often seen as a hedge and safe haven against stock market downturns.*
Global Oil Markets	*Brent Crude Oil Price*	*The price of oil, controlling for oil price tensions and representing the supply and demand dynamics of this global commodity, often seen as an indicator of inflation and an inverse component of stock markets*

3.2.3. TED spread

Wang and Park (2021) identified significant movements in the TED Spread in response to pandemic developments. This spread determines the risk premium charged on interbank loans by calculating the difference between the yield on a three-month U.S. Treasury Bill (a risk-free loan) and the three-month LIBOR USD Rate (a top-rated interbank loan), thus effectively 'pricing money' in the global banking system and providing the market with an indicator of the perceived credit risk in the economy. As per (Mayberger, 2014), the TED Spread is also used as a proxy for developments in monetary policies conducted by central banks in response to the recessive consequences of the COVID-19 pandemic.

3.2.4. Gold

Gold has consistently been found to be a flight to safety and a safe-haven hedging asset against equity market downturns (Gürgün & Ünalmış, 2014; Adekoya et al., 2021; Yousaf et al., 2021), warranting its inclusion in this analysis.

3.2.5. Brent crude oil

As with gold, the financial theory holds that oil shares an inverse relationship with stock markets Arfaoui and Rejeb (2017). However, as Cong et al. (2008) highlight, the literature is divided. Financial markets typically interpret increases in oil prices as an increase in the cost of energy and, by proxy, an increase in the cost of doing business. Hickman et al. (1987) identified that for every 1% increase in the price of oil, economic activity decreased by between 0.04% and 0.07%. However, it is arguable that COVID-19 has presented a rebuttal to this established economic relationship. During pandemic-induced economic shutdowns, the price of oil may instead be observed as a positive economic indicator, signaling a 'restarting' of economies and a resurgence in economic demand and activity (O'Donnell et al., 2021). Ashraf (2020) identified that turbulent demand, supply, and price dynamics within oil markets

Table 3
Descriptive statistics for international financial markets, COVID-19 Cases, COVID-19 Fatalities, and COVID-19 Vaccinations from January 2021 to June 2021. To maintain symmetry across financial markets, the daily log-return was chosen for consistency across indices. A simple arithmetic growth rate was calculated for all related COVID-19 statistics in parallel with the reporting methods used by several media outlets throughout the pandemic. The below statistics represent the 1-day growth rate in the cumulative number of cases, fatalities, and vaccinations.

Country		Daily Growth:	Mean	Std. Dev.	Minimum	Maximum
China	*(n = 94)*	Index Returns	0.02%	1.08%	−2.30%	3.06%
		Cases ^{TOTAL}	0.05%	0.08%	0.00%	0.50%
		Fatalities ^{TOTAL}	0.00%	0.00%	0.02%	0.02%
		Vaccinations ^{TOTAL}	6.05%	18.85%	2.01%	122.22%
Japan	*(n = 71)*	Index Returns	−0.06%	1.31%	−4.07%	2.38%
		Cases ^{TOTAL}	0.80%	0.58%	0.20%	2.97%
		Fatalities ^{TOTAL}	0.81%	0.51%	0.20%	2.50%
		Vaccinations ^{TOTAL}	23.51%	87.05%	0.21%	724.71%
U.K.	*(n = 81)*	Index Returns	0.06%	0.84%	−2.47%	2.41%
		Cases ^{TOTAL}	0.42%	0.66%	−0.11%	4.55%
		Fatalities ^{TOTAL}	0.53%	0.79%	0.01%	4.80%
		Vaccinations ^{TOTAL}	3.71%	3.91%	0.90%	26.01%
Italy	*(n = 92)*	Index Returns	0.12%	0.94%	−2.44%	3.12%
		Cases ^{TOTAL}	0.76%	0.58%	0.17%	3.96%
		Fatalities ^{TOTAL}	0.58%	0.42%	0.16%	2.82%
		Vaccinations ^{TOTAL}	5.81%	7.16%	1.84%	43.40%
Spain	*(n = 89)*	Index Returns	0.11%	0.98%	−2.89%	2.00%
		Cases ^{TOTAL}	0.68%	0.92%	−2.32%	5.27%
		Fatalities ^{TOTAL}	0.49%	0.41%	0.08%	1.90%
		Vaccinations ^{TOTAL}	6.11%	8.24%	1.38%	48.79%
Germany	*(n = 104)*	Index Returns	0.11%	0.97%	−2.72%	2.14%
		Cases ^{TOTAL}	0.76%	0.43%	0.19%	2.46%
		Fatalities ^{TOTAL}	1.15%	1.02%	0.14%	4.44%
		Vaccinations ^{TOTAL}	6.00%	4.48%	1.81%	28.34%
France	*(n = 104)*	Index Returns	0.16%	0.77%	−2.04%	2.06%
		Cases ^{TOTAL}	0.93%	0.52%	0.00%	2.92%
		Fatalities ^{TOTAL}	0.60%	0.31%	0.00%	1.33%
		Vaccinations ^{TOTAL}	13.49%	23.07%	2.31%	117.71%
U.S.A.	*(n = 95)*	Index Returns	0.11%	0.93%	−2.57%	2.38%
		Cases ^{TOTAL}	0.62%	0.76%	0.10%	4.57%
		Fatalities ^{TOTAL}	0.61%	0.54%	0.11%	2.91%
		Vaccinations ^{TOTAL}	6.66%	13.72%	0.40%	111.02%
India	*(n = 86)*	Index Returns	0.06%	1.31%	−3.87%	3.10%
		Cases ^{TOTAL}	1.09%	1.46%	0.09%	5.22%
		Fatalities ^{TOTAL}	0.84%	1.26%	0.06%	4.64%
		Vaccinations ^{TOTAL}	7.33%	8.72%	0.28%	48.63%
World	*(n = 93)*	Index Returns	0.11%	0.80%	−2.04%	3.07%
		Cases ^{TOTAL}	0.77%	0.58%	0.27%	3.59%
		Fatalities ^{TOTAL}	0.71%	0.45%	0.37%	2.64%
		Vaccinations ^{TOTAL}	7.41%	13.34%	1.33%	107.79%

Table 4
Results for models (1) to (10) from January 2021 to June 2021, representing the optimal stepwise regression model for each of the ten regions under the Bayesian Information Criterion. The equity market index accompanying each region (Equity Index Price) is listed from left to right, beginning with the Chinese SSE 180 index. A number without parentheses represents a regression coefficient, while a number inside parentheses represents a standard error.

Dependent Variable: Equity Index Price										
	SSE	NIKKEI	FTSE 100	FTSE MIB	IBEX 35	DAX	CAC	S&P 500	BSE	MSCI
	CHINA	JAPAN	U.K.	ITALY	SPAIN	GERMANY	FRANCE	U.S.A.	INDIA	WORLD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Independent Variable										
Volatility	−1.268	−143.514***	−17.706***	−137.037***	−27.089***	−0.1605***	−25.480***	−14.869***	−250.625***	−0.209***
(Standard Errors)	(1.396)	(8.967)	(2.276)	(10.277)	(3.726)	(0.0126)	(1.935)	(1.049)	(61.765)	(0.740)
Cases	−28.222**	−1.397***	−0.037647***	0.042***	−0.030***	0.0002***	0.008***	0.007***	0.366***	−0.00002***
(Standard Errors)	(12.964)	(0.112)	(0.0031)	(0.004)	(0.003)	(0.00001)	(0.001)	(0.001)	(0.061)	(0.00001)
Vaccinations	0.0001***	0.010***	0.001057***		0.003***		0.001***	0.0003***	−0.047***	−0.001***
(Standard Errors)	(0.00003)	(0.003)	(0.00005)		(0.0001)		(0.0001)	(0.00003)	(0.005)	(0.0001)
Oil			11.6985***	34.851***	33.767***	−0.032***	8.391***		194.950***	−0.082***
(Standard Errors)			(2.557)	(8.694)	(4.308)	(0.012)	(1.496)		(27.049)	(0.024)
Gold	0.476***	6.575***			−1.114***	0.004***		0.589***		−0.004**
(Standard Errors)	(0.104)	(1.12)			(0.282)	(0.001)		(0.079)		(0.001)
LIBOR-OIS	−64.631***	−9392.123***		12,607.040**						
(Standard Errors)	(16.013)	(3213.69)		(3786.297)						
TED Spread	217.638***	−10,217.450***		1836.190*				−687.515***		
(Standard Errors)	(43.931)	(2806.34)		(713.74)				(223.153)		
Constant	4338.869***	27,135.600***	8283.8602***	23,009.700***	10,496.060***	23.822***	5367.039***	2684.857***	41,906.680***	63.875***
(Standard Errors)	(930.838)	(1.566e+02)	(218.34)	(582.388)	(652.917)	(1.385)	(96.455)	(200.311)	(2075.40)	(3.689)
Observations	94	71	81	92	89	104	104	95	86	93
R^2	0.3922	0.8989	0.9191	0.949	0.938	0.9544	0.9799	0.9695	0.5916	0.953
Adjusted R^2	**0.3677**	**0.8894**	**0.9149**	**0.9461**	**0.9344**	**0.9526**	**0.9791**	**0.9678**	**0.5726**	**0.950**
Res.Std.Error	61.28	202.8	50.75	217	81.02	0.2945	43.52	27.48	791	19.421
	(df = 88)	(df = 64)	(df = 76)	(df = 86)	(df = 83)	(df = 99)	(df = 99)	(df = 89)	(df = 81)	(df = 87)
F Statistic	16***	94.84***	216***	320.4***	251.705***	518.3	1205	566.4***	31.14	350.713***
	(df = 5; 88)	(df = 6; 64)	(df = 4; 76)	(df = 5; 86)	(df = 5; 83)	(df = 4; 99)	(df = 4; 99)	(df = 5; 89)	(df = 4; 81)	(df = 5; 87)

Table 5
Results for models (1) to (10) from July 2021 to December 2021, representing the optimal stepwise regression model for each of the ten regions under the Bayesian Information Criterion. The equity market index accompanying each region (Equity Index Price) is listed from left to right, beginning with the Chinese SSE 180 index. A number without parentheses represents a regression coefficient, while a number inside parentheses represents a standard error.

Dependent Variable: Equity Index Price										
	SSE	NIKKEI	FTSE 100	FTSE MIB	IBEX 35	DAX	CAC	S&P 500	BSE	MSCI
	CHINA	JAPAN	U.K.	ITALY	SPAIN	GERMANY	FRANCE	U.S.A.	INDIA	WORLD
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Independent Variable										
Volatility	−5.842***	−112.980***	−20.669***	−114.769***	−10.194	−0.160***	−37.721***	−17.680***		−0.551***
(Standard Errors)	(1.226)	(24.325)	(1.202)	(9.128)	(20.508)	(0.011)	(2.627)	(1.630)		(0.042)
Cases	−31.769***	0.539***		−0.049***		−0.00002***	0.011***		5.913***	−0.003***
(Standard Errors)	(8.702)	(0.063)		(0.014)		(0.00000)	(0.001)		(0.227)	(0.001)
Vaccinations	0.0004***	−0.003***	0.0005***	0.004***				0.001***	−0.016***	0.0001***
(Standard Errors)	(0.0001)	(0.0005)	(0.00002)	(0.0004)				(0.00003)	(0.001)	(0.00002)
Oil	−2.568***	32.907***			66.432***	−0.054***	−12.438***	−4.363***	176.881***	−0.130***
(Standard Errors)	(0.901)	(10.927)			(12.560)	(0.006)	(1.703)	(0.872)	(14.074)	(0.023)
Gold				3.568***	5.661**	0.005***		0.826***		0.025***
(Standard Errors)				(1.092)	(2.346)	(0.001)		(0.147)		(0.004)
LIBOR-OIS					−761.473***		−970.462***			
(Standard Errors)					(1275.244)		(179.917)			
TED Spread							1177.023***		4808.347***	
(Standard Errors)							(94.463)		(1015.568)	
Constant	5725.788***	25,884.830***	6851.696***	20,072.740***	11,322.860**	31.969***	7071.410***	2632.600***	−88,921.000***	150.434***
(Standard Errors)	(567.938)	(970.608)	(31.644)	(1979.621)	(4484.320)	(2.163)	(154.629)	(277.922)	(4591.795)	(18.616)
Observations	102	92	97	98	104	104	104	99	89	102
R^2	0.4253	0.5743	0.8543	0.8498	0.6482	0.8389	0.8523	0.8928	0.9484	0.8612
Adjusted R^2	**0.4075**	**0.5607**	**0.8520**	**0.8450**	**0.6370**	**0.8338**	**0.8464**	**0.8894**	**0.9467**	**0.8556**
Res.Std.Error	50.42	591.8	46.27	325.5	136	0.334	83.51	44.95	627.8	1.119
	(df = 97)	(df = 87)	(df = 94)	(df = 93)	(df = 98)	(df = 99)	(df = 98)	(df = 94)	(df = 84)	(df = 96)
F Statistic	23.87***	42.16***	375.2***	178.2***	58.03***	164.1	144.3	262.4***	565.2	155.1***
	(df = 4; 97)	(df = 4; 87)	(df = 2; 94)	(df = 4; 93)	(df = 5; 98)	(df = 4; 99)	(df = 5; 98)	(df = 4; 94)	(df = 4; 84)	(df = 5; 96)

directly preceding the COVID-19 pandemic significantly impacted financial markets, making it a relevant and insightful control variable for this analysis.

Guided by financial theory and relevant financial literature, the above indicators provide us with a continuous and temporal dataset that can be used to analyze the evolving impact of COVID-19 on financial markets. Additionally, this significance is analyzed while controlling for investor sentiment, volatility, economic health, monetary policy, counterparty credit risk, liquidity risk, safe-haven asset demand, and the price of oil. In the following section, the stepwise regression methodology implemented will be outlined.

3.3. Methodology

With seven potential stock market predictors identified above, there are 2^7 possible model combinations that could be used to explain index prices in each country. To isolate and identify the most significant and explanatory set of predictors from the 128 potential model combinations, a method of variable selection known as stepwise regression will be employed. As with any multiple linear regression analysis, this study aims to find an optimally weighted average of the above predictor variables to explain index prices. As such, the combination of explanatory variables that render the 'COVID-19 Cases' or 'COVID-19 Vaccinations' insignificant can be justified as the combination of market factors influencing equity index price dynamics during COVID-19. Each model takes the form:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \ldots + \beta_k X_{ik} + \varepsilon_i \quad [1]$$

Where β_0 denotes the intercept of the model, with each ensuing β_k coefficient reporting the optimal descriptive weight associated with each of the explanatory variables X_{ik}. As such, a model is constructed for each of the territories outlined in Table 3 (ranging from $i = 1\ldots10$), using each of the variables outlined in Section 3.2 (ranging from $k = 1\ldots7$). As such, the same seven controlling factors are considered for each territory examined, with the final variables evident in Table 4 and Table 5 representing the most significant and explanatory model remaining. The stepwise process begins with an intercept-only model to construct the optimal fitting model for each region. It starts with forward selection, thus avoiding the challenges of confounding variables faced by backward selection methods (Lynn, 2003). The model considers all variables and first adds the variable which provides the most significant increase in the model's fit. The model is then reassessed to examine if any of the current variables in the model have now been made redundant or insignificant as a result of this new variable. If so, they are eliminated from the model. The process then repeats in iterative steps, or a stepwise approach process backward and forward until the model is satisfied as having the most optimal fit, where no more variables can be added or removed which would improve its fit.

Other methodologies such as LASSO (Least Absolute Shrinkage and Selection Operator), Ridge, and Elastic Net Regression were also considered. Stepwise regression has been the subject of critique in the literature by James et al. (2021) and Hastie et al. (2009), who, for example, describe its potential to underestimate and overestimate the significance of different combinations of variables in a final model. However, the above alternatives are subject to similar regression inaccuracy and bias. Lasso, Ridge, and Elastic Net Regression operate by penalizing the log-likelihood score that dictates the magnitude of the coefficients within the model. This has the effect of counterbalancing the existing bias within the data by including user-defined bias into the model (Shannon, 2020). Therefore, such methodologies introduce a practitioner bias into the model to enhance predictions by removing variables that increase the error term. Since it is a means of introducing bias into the estimates, the estimates can no longer be relied upon for explanatory purposes. In other words, these alternatives are better suited for the purposes of prediction.

As this study focuses on an exploratory and explanatory analysis of COVID-19 and financial markets, the Stepwise Regression methodology was chosen to identify a selection of COVID-19-related and financial market-related variables significantly associated with benchmark indices worldwide. Despite critique, the literature utilizes stepwise methodologies for similar exploratory research questions. Using a similar stepwise logistic regression methodology, Ou and Penman (1989) composed an earnings prediction model using a large selection of available inputs from publicly available financial statements. This was implemented to direct long and short company stock positions pre-announcement. Similarly, both Enke and Mehdiyev (2013) and Cheng (2015) forecasted the future price of equity indices in hybrid prediction models using a stepwise regression analysis, employing a large set of both financial market and economic indicators as inputs. Therefore, the same methodology was chosen for this analysis to highlight whether the growth in COVID-19 remained statistically significant in the presence of other theoretical market drivers.

The metrication of 'optimal fit' used in this stepwise regression analysis is the Bayesian Information Criterion (BIC) (Equation (2)). Model fit is computed as:

$$BIC = n\log(SSE) - n\log(n) + \log(n)(k+1) \quad [2]$$

Where the total count of observations is denoted by n, the sum total of the squared errors is represented by SSE, and the number of predictor variables in the model is denoted by k. The Bayesian Information Criterion (BIC) from Schwarz's (1978) analysis was chosen as the basis for variable and model selection within the complete set of pre-determined variables. Favoring minimal residual errors, BIC is a goodness of fit measure that penalizes excessive predictor variables, aiding in diminishing the issue of model overfitting. It is an estimate of a constant plus the relative distance between the data's unknown true likelihood function and the entire model's fitted likelihood function.

The BIC favors a more parsimonious model relative to other stepwise penalization criteria, thus appropriately penalizing excessive model parameters. Shmueli's (2010) study "To Explain or Predict" states that the BIC is better suited for explanation rather than prediction. Therefore, the BIC was chosen for this analysis due to the exploratory nature of this study and in favor of a parsimonious model.

Using the above methodology and successively excluding insignificant explanatory variables, this study aims to find the optimal market model for explaining index prices. Therefore, the final model fit may exclude the influence of 'COVID-19 Cases or 'COVID-19 Vaccinations' as statistically significant predictors, while the remaining variables in each model will highlight the driving market forces which determined index prices during this wave of the recent COVID-19 pandemic. From this methodology, we also theorize that if, for example, a flight to safe-haven assets such as Gold was the primary instigator of market decline, then Gold should replace or make our COVID-19 variable redundant in our model.

4. Results

Table 3 presents summary statistics for the financial market and COVID-19 data for all ten regions. With regard to stock market performance, the maximum daily index return was +3.12% (*Italy – FTSE MIB Index*) on the March 5, 2021. This starkly contrasts with 2020, which saw the *FTSE MIB* suffering the most significant negative return of the six indices (−16.92%) on the 21st of February 2020. The minimum index daily return observed in this analysis was −4.07% (*Japan – NIKKEI 225 Index*) on the 25thth of March 2021. For growth of COVID-19, the largest single-day rise in cumulative case numbers was 5.27% (*Spain – 19*th *January*). Notably, on the same date, the highest single-day growth in cumulative fatalities was also observed, at 4.8% (*U.K. – 19*th *January*). However, the mean increase in case numbers was far lower, remaining in the range of 0.02% (*China*) to 0.12% (*Italy*) for all regions, with India an outlier at 1.09%. Daily growth in fatalities was higher, with the average range between 0% (*China*) and 0.84% (*India*), with the global mean daily increase in deaths at 0.71%. India led the analysis with the highest mean daily growth in total vaccinations at 23.51%, with the U.K. seeing the lowest daily growth at 3.71%. Meanwhile, the global cumulative increase in vaccinations grew at 7.41%. As can be seen from all regions examined, the rollout of vaccinations far exceeds the growth in the virus during this timeframe. Fig. 2 illustrates the price-action of the ten major equity indices over the duration of the pandemic, including the initial shock of the pandemic in early 2020 up to the rollout of vaccination programs in 2021. The price behavior of the indices in response to critical announcements surrounding the pandemic and vaccine developments can also be observed in Fig. 2, with a synchronous jump in global markets on November 9th, 2020, coinciding with the first successful vaccine trial announced by Pfizer.

The final models determined by the Stepwise Regression methodology for the initial impact of vaccinations on financial markets (January 2021 to June 2021) are presented below in Table 4. With equity index price as the dependent variable and the selection of COVID-19 and financial indicators as independent variables, explanatory power was observed for models (1) to (10), with China (1), Japan (2), the UK (3), Italy (4), Spain (5), Germany (6), France (7), the USA (8), India (9) and the World (10) representing the ten regions under scope in this analysis. Notably, while R^2 values close to or above 90% were observed in models (2) through (8), the adjusted R^2 for China (1) was significantly lower at just 37%. This echoes the findings of previous studies, where a reduced level of explained variance for Chinese stock markets was also observed (O'Donnell et al., 2021). The other emerging market region examined, India, also displayed a distinctly lower level of explained variance with an R^2 of just 57%. Overall, Table 4 shows the sustaining significance of COVID-19 in financial markets, with COVID-19 cases and vaccinations significantly associated with equity index prices in ten and eight of the regions, respectively. Additionally, Table 5 illustrates the final model selection for the period encompassing July 2021 to December 2021, highlighting a distinct change in financial market drivers in the latter half of the year, as the positive impact of vaccination developments had arguably been realized. Section 5 discusses these findings on a factor-by-factor basis, detailing the primary drivers of global stock markets and the variance in drivers across regions as the pandemic evolved. Thereafter, this study investigates the evolving dynamics that emerged during the latter half of 2021 as vaccination programs progressed.

Table 6
The growth in total cases for each region examined as a percentage of the total cases recorded from January 1st, 2021, to June 30th, 2021. The period under analysis shows that India experiences the largest growth in cases of the 10 regions examined (162.1%), with China recording the lowest (4.5%).

Country		Growth in Total Cases 01/01/2021–30/06/2021
	China	4.5%
	Japan	74.9%
	U.K.	40.6%
	Italy	100.2%
	Spain	81.5%
	Germany	104.8%
	France	110.7%
	U.S.A.	78.6%
	India	162.1%
	World	106.3%

5. Discussion and implications

5.1. Market drivers

5.1.1. COVID-19

5.1.1.1. Cases. Table 4 confirms the significant association between stock markets and COVID-19 cases, with negative coefficients observed for China (1), Japan (2), the UK (3), Spain (5), and World (10) models. These findings are in line with the aforementioned body of literature from the early stages of the pandemic, showing that as case numbers grew, index prices suffered a price decrease. Positive coefficients were observed for Italy (4), Germany (6), France (7), the USA (8), and India (9), indicating that as COVID-19 cases grew in these regions, so too did equity index prices. A previous investigation into the early stages of the pandemic failed to find significance in Chinese markets, making these findings noteworthy. As the pandemic progressed, China undertook a 'zero-COVID' approach to containment. From this, the government met any increase in case numbers with an immediate and significant response. Table 6 illustrates the growth in total cases for each region during this study's period, illustrating how the recent 'growth' of the virus in China pales compared to the other areas examined. Despite this, COVID-19-related data remains significant in China. It can be suggested that as the pandemic progressed, resurgences in case numbers presented a more substantial threat to the status quo in China and an increased probability of economic disruption due to renewed lockdowns. On the other hand, in the period of this analysis, other regions such as Europe and the USA remained under consistent levels of restrictions, explaining the lack of significance despite such a 'growth' in case numbers. In this case, societal restrictions and the potential for unexpected economic disruption had arguably reached its peak due to the consistent level of restrictions in place due to the sustained growth of the virus throughout society.

For India and the USA, recent research finds that although individual sectors suffered a significant impact due to the pandemic, benchmark indices remained resilient in the context of average returns (Shankar & Dubey, 2021). Additionally, questions surrounding the disconnect between Indian stock markets and true economic realities have been raised as stock markets soared alongside growth in the virus. A report by the Indian Department of Economic Affairs (2020) reports a widening gap between consumer sentiment, measures of economic activity, and stock market returns. Similarly, Ray and Pal (2022) uncover this disconnect for both India and the USA, whereby stock market benchmarks continued to rise in the face of falling economic indicators. Here, the research theorizes that a sizeable proportion of economic stimulus packages worldwide instead acted as a buffer within the financial system against the real and significant impact of COVID-19 on fundamental economic health. These findings align with the aforementioned results, which saw stock markets and COVID-19 grow in tandem. It should be noted that models for both China and India have a significantly reduced level of explained variance, with R^2 values of 0.37 and 0.57 observed, respectively. As stated above, a complete disconnect between Indian economic reality and stock market performance explains these findings. For the case of China, the global origin of the virus, this disparity is discussed in detail in Section 5.2.

5.1.1.2. Vaccinations. The effect of total vaccinations per country remained significant in eight of the ten models. Namely, in China, Japan, the UK, Spain, France, the USA, India, and World models. Positive coefficients were observed for all models except India and World models, indicating that stock markets in that region rose as more of the population was vaccinated. These findings highlight the significant impact of positive sentiment surrounding COVID-19 vaccinations on financial markets. While this finding emerges from our day-by-day regression analysis, visually, this finding and the overall positive boost to stock markets as a result of vaccine developments are also evident in Fig. 2. Here, the synchronous jump in global markets on November 9th, 2020, coincided with Pfizer's first noteworthy vaccine announcement. Chan et al. (2021) echo these findings, showing both economically and statistically significant reactions of global stock markets to different phases of the vaccine's clinical trials. Additionally, Acharya et al. (2021) constructed an asset pricing model to quantify the value of a 'COVID-19 cure' for financial markets. Through this, it was found that agents place almost as much weight on the ability to resolve the uncertainty of a 'cure' as they do on the value of the 'cure' itself. In other words, the expectations of investors have the potential to drive markets. This finding explains the significant jump in stock markets on November 9th, 2020, before any vaccine had even been administered.

Notable from our findings is the negative coefficients observed for the Indian and World models and the absence of significance observed for the Italian model. Examining vaccine sentiment and inoculation statistics from these regions, a distinct hesitancy is observed for both India and Italy. Danabal et al. (2021) observed the prevalence of vaccine hesitancy in rural communities in India at 40.7%, with 19.5% of respondents classified as vaccine deniers. Similarly, Chandani et al. (2021) found that almost 70% of the population had concerns regarding the vaccine, with more than a fifth of respondents unaware of the vaccine. As such, our results are unsurprising for a region with significantly less knowledge of the vaccines and, thus, a significantly reduced rate of inoculation. Vaccination rates for an area opposed to such measures are an insignificant and inaccurate indicator of pandemic 'recovery.' In addition to inoculation and approval rates, these findings also point to the asymmetry between developed and emerging markets and the impact of vaccinations. Routabi et al. (2022) found that the effects of vaccinations were more substantial for developed markets than for emerging ones. We also observe this in our analysis. India, the only emerging market in our study, was not positively associated with vaccine developments.

On the other hand, regions with high vaccination rates and low vaccine hesitancy will observe such vaccine developments as an effective measure to quell the pandemic and reduce the financial disruption it has caused, thus positively affecting financial markets. To a lesser degree, hesitancy has been observed in Italy by (Paladini et al., 2021). In 2017, 20% of respondents believed in the harmfulness of vaccines, with 30% not having trust in the scientific community. Cantoli et al. (2021) observed similar results during

the pandemic, with 16% of people likely to refuse the vaccine. It is evident that in both India and Italy, societal hesitancy to vaccines is present, explaining the results in this study.

For the World model, the negative coefficient may be explained by including COVID-19 data for regions not adequately captured by the global equity index. With over 1563 constituents, the index aims to capture stock market performance across large and mid-cap companies in 23 developed markets. However, weightings in the index for emerging markets or countries more heavily affected by the pandemic in recent months (such as India, Brazil, Turkey, and Africa) are underrepresented in equity index price performance. Therefore, we theorize that while analyzing a static global equity index such as the MSCI World, the shifting spatiotemporal nature of the COVID-19 virus as it shifted from country to country and the inequality of vaccine distribution worldwide gave rise to these findings in our model.

Our results concur with the current literature and find that the proliferation of COVID-19 vaccines to the broader population was positively associated with equity index prices. Chan et al. (2022) also observed this and found that global stock markets responded positively to the commencement of clinical trials. Routabi et al. (2021) and Khalfaoui et al. (2021) echo these findings, whereby COVID-19 vaccinations significantly and positively influenced stock markets. These results also highlight the importance and pertinence of equitable vaccine distribution among both developed and emerging markets. The positive impact of vaccinations was not observed for the India and World models in this analysis. As a result, to mitigate the effects of COVID-19 on global equity markets, policymakers should ensure the equitable and fair distribution of vaccinations to both developed and emerging markets. Likewise, our results suggest that investors should monitor vaccination metrics across markets during future pandemics or comparative adversarial events to effectively hedge and diversify portfolios exposed to different geographical regions where vaccination approvals and administrations vary.

5.1.2. *Implied volatility*

Consistent with previous research discussed in Section 3.2, implied volatility measures remained a significant indicator across all models. This finding was expected, as implied volatility measures have historically shared an inverse relationship with stock markets. Recently, Albulescu (2021) empirically confirmed this relationship, illustrating how official announcements regarding COVID-19 cases and fatalities directly enhanced the realized volatility of the S&P 500 index.

5.1.3. *Credit and liquidity risk*

The TED Spread and LIBOR-OIS Spread were used in this analysis to measure monetary policy, credit risk, and liquidity risk and as a barometer for the overall level of fear in the banking sector. Table 4 shows that the LIBOR-OIS spread remained statistically significant for China, Japan, and Italy, with negative coefficients observed for China and Japan and a positive coefficient observed for Italy. In the case of Italy, the counterintuitive correlation between credit and liquidity risk measures and stock markets may be explained by the risk-averse and pro-deficit approach taken by the Italian government in recent years. Italy currently holds the second largest debt pile in the EU, with a debt-to-GDP ratio of 160% reported by Albanese and Migliaccio (2021). An increase in the fiscal deficit can boost a

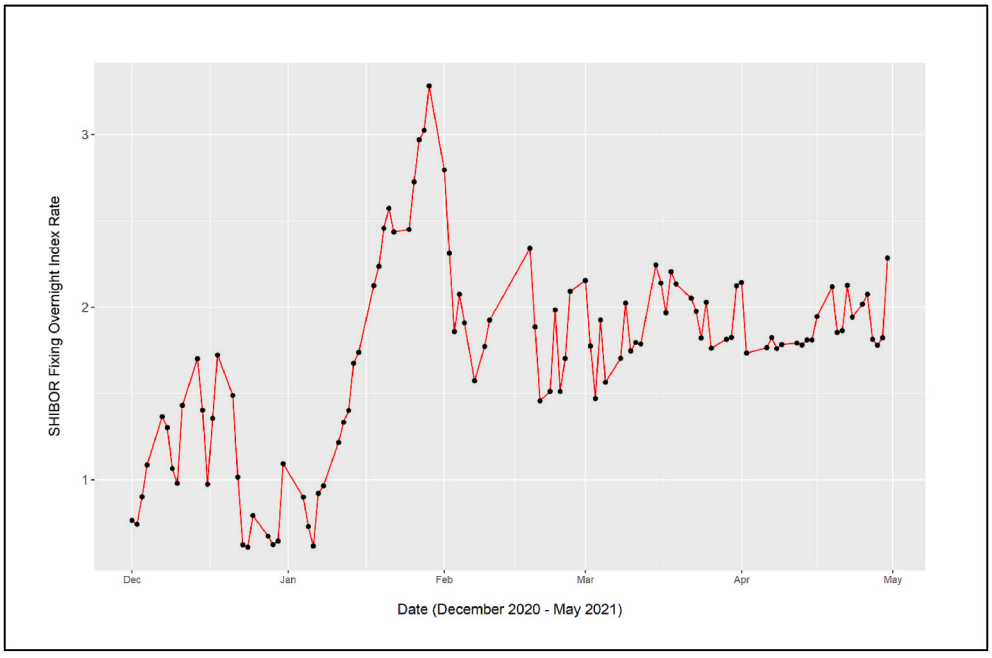

Fig. 3. Illustrates the sharp spike in short-term lending rates (SHIBOR Overnight Indexed Swap Rate) in response to restrictive sentiment emerging from the People's Bank of China surrounding future lending levels in the property sector and the broader economy.

sluggish economy through direct cash infusions to distressed parties. Silva (2021) quantitatively assessed fiscal deficits and bank credit risk, finding that deficits act as an essential variable for mitigating credit risks, revealing the government's ability to curb losses and stabilize macroeconomic conditions. As such, Italy's substantial fiscal deficit compared to the other European regions examined can be used to explain the positive correlation between traditional measures of banking and liquidity risk and stock markets. Therefore, we theorize that while broad-based European standards of such risks increased, this did not negatively impact Italian benchmark indices due to the economy's distinct fiscal and monetary environment. Such theories are supported by recent economic data emerging from Italy, where despite a significant fiscal deficit, stronger-than-expected economic rebounds post-COVID are improving fiscal outruns, according to Fitch (2021), and increasing GDP growth forecasts to 6%.

On the other hand, as credit conditions deteriorated in Chinese markets, our findings show a negative impact on Chinese stock markets. Given the region's current credit and lending environment, this finding is intuitive and insightful. As China leads the race in pandemic recovery, the state-controlled central bank must now prepare to guard against an overheating economy. Theoretically, a central facility may need to tighten policy to achieve this. In other words, raise the target interest rate, constrict lending, and subsequently dampen growth.

As can be seen in Fig. 3 below, fears of tightening policy implementations in China spiked short-term lending rates in early January 2021. This occurred as the People's Bank of China instructed domestic and foreign lenders operating in the country to keep the level of loans at the same level year-on-year, translating into a forward-looking drop in bank lending (Hale et al., 2021). A reduction in banking sector lending will consequently lead to a deceleration in credit growth within the economy. From Fig. 4, a recent slowdown in credit growth is already evident within China. This can be seen through the Credit Impulse Indicator, which illustrates the monthly change in new credit as a proportion of GDP. As Bell (2021) states, this indicator is a valuable gauge of Chinese macroeconomic policies and a leading indicator for global economic activity, whereby a drop into negative territory may signal an end to the current business cycle. As can be seen together from Figs. 4 and 5 below, spiking short-term lending rates, increased fears of tightening policies, and a tumbling Credit Impulse Indicator since the beginning of 2021 all suggest a turbulent credit and lending environment in China going forward, thus explaining the negative significance between LIBOR-OIS rates and Chinese stock markets in this analysis.

For the TED Spread, negative significance was observed for both the Japan and USA models, indicating that as this spread widened, equity index prices fell. This is in line with Wang and Park's (2021) study, which found that innovations in the pandemic led to a significant increase in the TED spread and a significant response in stock market returns. Historically, the TED Spread has risen as high as 4.5 in 2008, reflecting the rise in global anxiety surrounding the global financial crisis. Before COVID-19, the IMF (2020b) forewarned that 40% of corporate debt in developed markets would be exposed during a major global recession. As this downturn in markets came to fruition and COVID-19 took hold, economies began to shutdown, corporate liquidity dried up, and both the LIBOR-OIS and TED Spread rose to their highest levels since the crisis in 2008, with the TED Spread spiking to 1.42 on March 26th, 2020, (OECD, 2021). This corresponds with market dynamics at that time. In less than one month as the pandemic took hold, over $120 trillion was drawn on short-term credit lines by companies in American and European markets (Platt et al., 2020). As the subsequent pandemic-induced lockdowns were introduced, consumer demand quickly receded, corporations thus drew increasingly on short-term

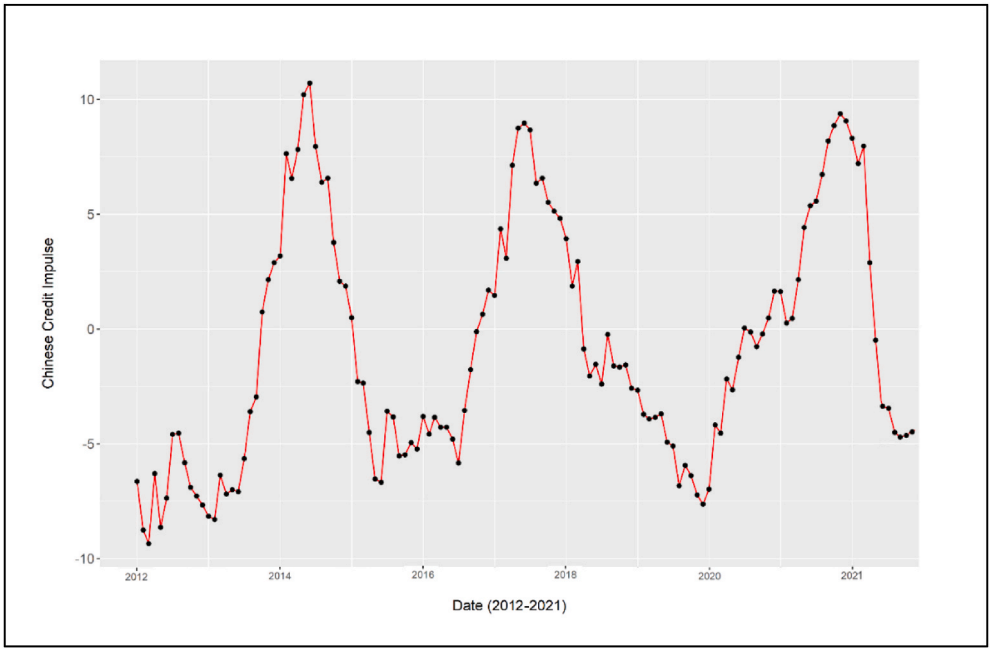

Fig. 4. Illustrates the Chinese Credit Impulse indicator from 2011 to 2021. This illustrates the monthly change in new credit as a proportion of GDP, whereby a drop into negative territory may signal an end to the current business cycle.

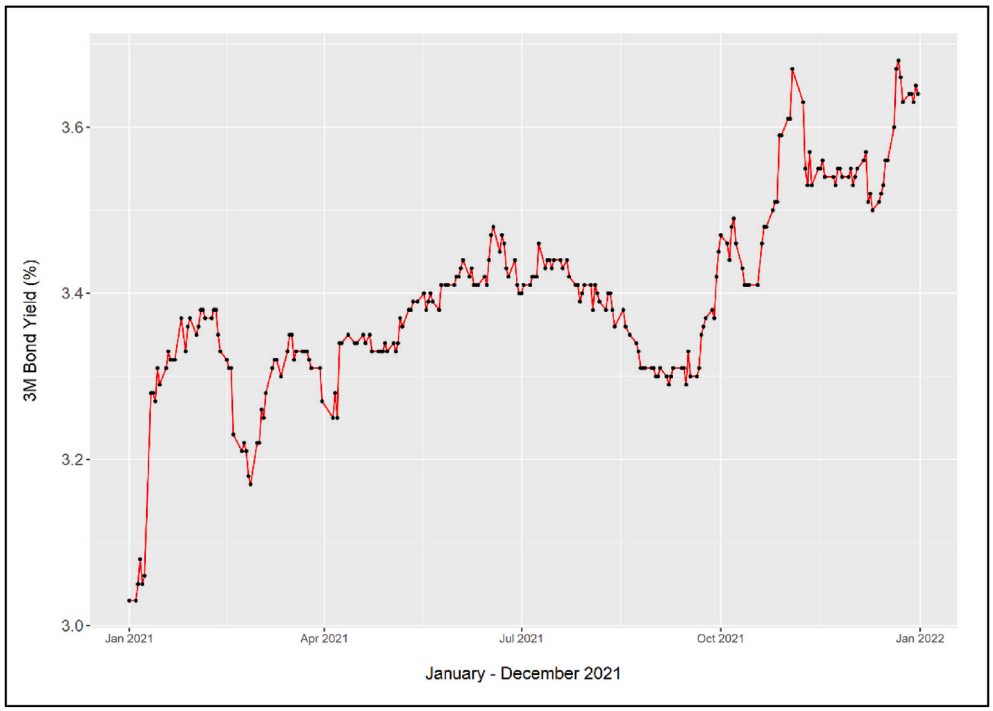

Fig. 5. Showcases the upward pressure on Indian Government Bond Yields as inflationary pressures entered the market amid record levels of borrowing, reaching 2-year highs.

credit lines, and the demand for liquid assets increased significantly, putting pressures on the funding and interbank markets (Bank of England, 2020). Therefore, the above findings confirm the significance and continuing relevance of the TED Spread and LIBOR-OIS spread during COVID-19 as essential indicators of insolvency fears, liquidity risk, and the overall risk within the global banking system.

5.1.4. Global oil markets

The price of oil remained positively and statistically significant across four of the five European countries examined in this analysis. Namely, the UK, Italy, Spain, and France. This differs from the findings of O'Donnell et al. (2021), whereby positive significance was observed for China, the U.K., the U.S.A., and the World models. As stated previously, in COVID-19 economic conditions, the price of oil represents a gauge of economic activity and demand, thus explaining the positive coefficients observed. As travel resumed and countries exited commercial lockdowns, the demand for oil rose, and commodity prices increased, signaling a revival of economic demand in financial markets. Although monetary theory dictates that oil and stock markets typically share an inverse relationship in a macroeconomic environment characterized by increasing global demand for industrial commodities, Kilian and Park (2009) found that stock markets remain resilient to rising oil prices. The variance in oil's significance across the two waves of the pandemic can arguably be explained by the lockdown measures taken in the respective regions. China's lockdown lasted until April 8th, 2020, while several states in the U.S.A. announced a complete exit from lockdown in early March 2021. On the other hand, European lockdowns were shrouded with uncertainty and persisted longer, relative to both China and the U.S.A. Therefore, for Europe, an indicator of reviving economic activity and aggregate demand would provide a more powerful message to these stock markets relative to other regions where restrictive lockdowns on commerce and travel were not as strong a consideration.

Similar findings have been observed throughout the pandemic, with a positive co-movement between oil price returns and stock price returns identified by Prabheesh et al. (2020) during the pandemic period. Mzoughi et al. (2020) identified a strong negative correlation between COVID-19 cases and the price of oil (−0.83), indicating that as the number of confirmed COVID-19 cases increased, oil prices decreased. As we have identified in this paper and in O'Donnell et al. (2021), the number of COVID-19 cases was negatively and significantly associated with stock market prices. These findings support the hypothesis that a nexus of causality exists between growth in COVID-19, oil price returns, and stock price returns. An increase in COVID-19 cases eroded aggregate demand in the global economy, decreasing oil prices and negatively affecting stock market prices. Therefore, the price of oil, significant in both waves of the pandemic thus far, should be considered a substantial factor in the reaction of stock markets to COVID-19. Mzoughi et al. (2020) also identified a strong negative relationship between oil prices and volatility, while our findings in Table 4 identify a negative relationship between volatility and equity market prices. Additionally, as can be seen from Table 4, the other positive relationship between oil and equity markets confirms the nexus that exists between these factors, showing that as aggregate demand and general economic activity recovers, oil prices rise, investor confidence increases, volatility decreases, and stock markets move upwards alongside this rise in oil.

5.1.5. Flight to safety & safe haven assets

Mixed findings were observed for Gold and its ability to hedge against equity market downturns. A significant and negative association was observed for Spain and World models, suggesting that the instinctive inverse relationship between gold and equity markets seen extensively in the literature (Ali et al., 2020; Beckmann et al., 2015; Chen & Wang, 2018) exists in these markets also. However, positive coefficients were observed for the China, Japan, Germany, and USA models, suggesting a coupled and correlated relationship between gold and equity markets. These mixed findings somewhat contrast the current literature on gold's ability to hedge against equity markets during COVID-19. Yousaf et al. (2021) found that gold possessed robust hedging and safe-haven characteristics during the early stages of the COVID-19 outbreak relative to the pre-pandemic period of 2015–2020. Similar hedging characteristics were observed by Akhtaruzzaman et al. (2021), but again, for the early stages of the pandemic up to March 16th, 2020. As the pandemic progressed, the study found a diminishment in gold's ability to act as a safe haven for international equity markets. This second phase of the virus (from March 16th, 2020, onwards in Askhtaruzzaman et al. (2020) and January 2021 onwards in this study) importantly includes a period composed of the V-shaped recovery and subsequent rise of equity markets. This V-shaped recovery is apparent in Fig. 2, where financial markets suffered a significant and sharp descent as the pandemic initially took effect before recovering with similar vigor in the proceeding weeks, creating the 'V-shaped recovery in index prices over time. An examination of gold in the post-financial crisis era by Shrydeh et al. (2019) found that the hedging effectiveness between stocks and gold diminishes as stock market capitalization increases. This concurs with the mixed results observed in this study for the latter stages of the pandemic, as global stock market capitalization rebounded and recovered significantly during this time (Fig. 2).

5.2. Implications of results

5.2.1. Unexplained Chinese stock market variance – what was different?

While the results and implications of key stock market drivers in other regions are discussed in detail above, the level of explained variance in model (1) for China is significantly lower than in models (2) through (8) and model (10), with an R^2 value of just 0.367 observed. This raises important questions surrounding the unique drivers and characteristics of Chinese stock markets, which were absent from these findings. The following section will briefly explore this topic, highlighting key differences in China's response to the pandemic and how this may have affected financial markets, a topic we intend to explore through further research.

5.2.2. Lockdown response – Chinese government

Firstly, the initial policy response by the Chinese government at the epicenter of the pandemic was swift and decisive. By January 23rd, 2020, strict lockdown measures were imposed in Wuhan and several Chinese cities, resulting in a complete halt to commerce, travel, and anything but the most essential operations. While this was met with skepticism by many parties, including Amnesty International (2020), the World Health Organization, in fact, praised the response for its effectiveness (Rauhala, 2020). By March 18th, China recorded no new cases of COVID-19. Elsewhere, the pandemic was only beginning to take hold, evidenced in Fig. 1. As such, despite the extreme measures taken, swift and decisive decision-making on lockdown policies ensured that a somewhat normal resumption of business activities was possible. China International Capital Corporation (CICC), one of China's leading investment banking firms, reported an overall work-resumption rate of 86% by April 15th, 2020, with the CICC Daily Production Activity Tracker (PAT) also reaching 75% of its pre-pandemic rates by March 5th (Tian & Meng, 2020). Meanwhile, Table 7 illustrates the lagging response of the other regions examined in this study, with lockdowns and stay-at-home orders implemented long after China's initial response. Although these dates relate to the initial onset of the virus in early 2020, this initial lockdown response laid the foundation for the economic responses thereafter and the ultimate failure or success of suppressing the virus during the proceeding waves. It can be argued that the disparity in the level of economic activity and overall sectoral activity in China versus the other regions examined results from asynchronous lockdown responses, resulting in the reduced R^2 value.

5.2.3. Central bank response – People's bank of China (PBoC)

The Federal Reserve implemented damage limitation policies from March 3rd, 2020, alleviating money market pressures by providing up to $175 billion in daily overnight secured loans and announcing a reduction of the Federal Funds Rate by 50 basis points (0.5%). Both actions attempted to promote investment and greater economic activity while ensuring a sufficient supply of reserves (Federal Reserve, 2020). Meanwhile, the PBoC implemented proactive measures over a month earlier, beginning on January 15th, with the announcement of a monetary policy package on January 31st' which included open market operations and central bank lending supports. By March 3rd, Funke and Tsang (2020) revealed the extensive policy response which had already taken place by the PBoC and the significant injection of targeted liquidity into the Chinese financial system, the extent of which is outlined in Table 8. Like the U.S.A., the U.K. and Eurozone also lagged behind the PBoC in their response, with policy announcements made on March 11th and 12th' respectively (Schleich & Paquet, 2020). Baldwin and Weder di Mauro (2020) report the almost unlimited "quantitative easing" provided by the Federal Reserve, E.C.B., and Bank of England, which included purchases of government bonds, commercial paper, and mortgage-backed securities. On the other hand, Funke and Tsang (2020) reveal China's contrasting focus on a more conservative approach, instead focusing on containing the nation's debt pile. Therefore, the targeted macro stimulus policies of the PBoC contrast

Table 7
Dates of restrictive lockdown policy implementation at the beginning of the pandemic. As the global origin of the virus, China was the first to implement lockdown policies on January 23rd, 2020, followed by Europe, India, the U.S.A., and Japan throughout March and April 2020.

Country		First Lockdown Start-Date
	China	January 23rd 2020
	Japan	April 16th 2020
	U.K.	March 23rd 2020
	Italy	March 9th 2020
	Spain	March 14th 2020
	Germany	March 16th 2020
	France	March 17th 2020
	U.S.A.	Between March 22nd and April 12th 2020
	India	March 25th 2020

Table 8
Summary list of economic policy responses by the People's Bank of China before any policy announcements from any of the other regions examined up to March 3rd, 2020. (Funke & Tsang, 2020). Significant economic supports were announced prior to any action taken by the other regions.

Date:	People's Bank of China Policy Response
31st January 2020	*Monetary Policy Package Announcement – Plan to provide sufficient liquidity to the market through open market operations, standing lending facilities, central bank lending, and central bank discounts.*
3rd February 2020	*Injection of 1.2 trillion RMB into the banking sector through reverse repo operations, with a reduction in repo rates by ten basis points (0.10%)*
7th February 2020	*Announcement of a 300 billion RMB special central bank lending facility, providing low-cost funds for bank lending, supporting pandemic prevention and control.*
10th February 2020	*Injection of 900 billion RMB in liquidity into the banking sector through reverse repo operations.*
20th February 2020	*1-Year Loan Prime Rate reduction of* 10bps *and 5-Year Loan Prime Rate by* 5bps.
25th February 2020	*Increase in the PBOC's re-lending and rediscount quota by 500 billion RMB for bank lending in order to support SMEs.*
3rd March 2020	*Additional 350 billion RMB special credit quota for loans issued to SMEs at preferential rates.*

starkly with the more extreme monetary and fiscal policies implemented by the other regions. As such, the PBoC's intentional avoidance of 'helicopter money'[1] or flood-like stimulus indicates a swifter but ultimately milder policy response when compared to the other regions examined. It can therefore be argued that this unique and novel approach taken by the PBoC to ensure ample reserves of commercial credit and liquidity aided in alleviating money market pressures and shielded financial markets when the global economic implications of the pandemic began to be realized in the proceeding months of 2020.

In addition to the response of the PBoC, additional focus should be directed towards the behavior of stock market participants in China, the current regulatory environment, and the overall levels of efficiency within the Chinese financial system. Firstly, despite clear and decisive actions taken to provide markets with adequate liquidity, short-term lending rates still experienced significant spikes in early 2021 as restrictive sentiment emerged from the PBoC surrounding future levels of lending in the property sector and broader economy (Fig. 3). This response of the Chinese financial system echoes that of Jo et al. (2018), who also identified a distinct lack of maturity in the Chinese interbank money market, whereby a sudden freeze in the market led to moments of market failure. This was evidenced by high and sustaining overnight SHIBOR rates during times of market uncertainty in their study, echoing the findings observed in this study. Additionally, liquidity shocks such as these can potentially transmit into other sectors of the wider economy. As the Chinese economy continues to defragment, empirical findings from Lu et al. (2018) now shed light on the transmissibility of shocks across the whole financial system. Through constructing an empirical model, strong evidence now exists that money market shocks can transmit liquidity shocks back and forth between China's banking sector and stock markets, reaffirming the negative significance of the LIBOR-OIS spread observed in this stock market analysis.

Similarly, it is noteworthy to discuss the regulatory environment surrounding the short selling of securities in Chinese stock markets. Despite milder short-selling restrictions imposed in several European markets during the pandemic (Siciliano & Ventoruzzo, 2020), the transparency of such regulations in China remains more restrictive and opaque. The literature is rich with evidence

[1] Coined by Friedman in his (1969) essay "The Optimum Quantity of Money", 'helicopter money' refers broadly to a situation in which a central facility prints new money or increases the money supply and distributes it to the population with the intention of monetary expansion and subsequent stimulation of growth.

supporting the hypothesis that active short selling in financial markets encourages liquidity, price discovery, and enhanced price efficiency (Diether et al., 2009; Boehmer, Jones, Wu, & Zhang, 2019). As a result, during downturns, short sellers can also exacerbate downward price movements (Geraci et al., 2018). Brunnermeier and Oehmke (2013) examined predatory short-selling, documenting that restrictions imposed on short-selling can, in fact, lead to higher probabilities of default and heightened levels of volatility. Additionally, Diamond and Veerechhia (1987) theoretically outline how short-selling bans decrease the efficiency of price discovery, widen bid-ask spreads, and thus contribute to a deterioration in market liquidity. Recent studies emerging from the COVID-19 pandemic echo these findings. Siciliano and Ventoruzzo (2020) confirmed the theoretical arguments made by Diamond and Verrecchia (1987), revealing empirical evidence that short-selling bans were not effective in stabilizing financial markets during the recent period of heightened uncertainty precipitated by COVID-19. The above findings reaffirm the significance of the LIBOR-OIS spread for Chinese stock markets in this analysis and the significant role that fears of credit and liquidity risk played. Immature interbank money markets, restrictive regulation on short selling, and a deteriorating credit situation in China contributed to the sustaining significance of credit and liquidity risk fears within Chinese stock markets throughout this analysis. The above market dynamics and unique aspects of the Chinese financial system are ripe for further research as the monetary, fiscal, and regulatory responses to the pandemic unfold in the coming months and years.

5.3. *Did COVID-19 remain significant? – June to December 2021*

Table 5 presents the same analysis described above for the period following the initial 6-month introduction of COVID-19 vaccination programs, covering July to December 2021. Several differences in the market models are observed as COVID-19 progressed, vaccinations rolled out, and society began to anticipate a return to normalcy. Firstly, eight of the ten models show a significant reduction in explainable variance through the observed adjusted R^2 values. From this, the same market factors which strongly influenced equity index prices in the first half of 2021 as vaccination programs began became less indicative of the underlying market forces which drove the markets in the latter half of the year. Examining the significance of the COVID-19-related data, an increased sensitivity to both increases in cases and vaccinations was observed for China alongside an increase in the R^2 value, whereby stock prices reacted negatively and positively to both factors, respectively. This aligns with the findings discussed in Section 5.1, whereby China undertook a significant 'zero-COVID' approach, reacting to even minor outbreaks of cases with swift containment measures (Gong et al., 2022; Lemaître, 2022). As such, for a society more prone to societal lockdowns in the face of even minor resurgences of the virus, the economic burden of increasing cases would be amplified, explaining these findings.

Mixed findings were observed in Europe, whereby the significance of COVID-19 cases became insignificant in the UK and Spain models. Meanwhile, vaccinations became insignificant or lost explanatory power in the UK, Spain, Germany, and France models. In the USA, cases lost significance in the final model. At the same time, an increase in the vaccination coefficient suggests a stronger positive relationship between stock markets and the indicator of pandemic recovery. For India, the sustaining inverse relationship between

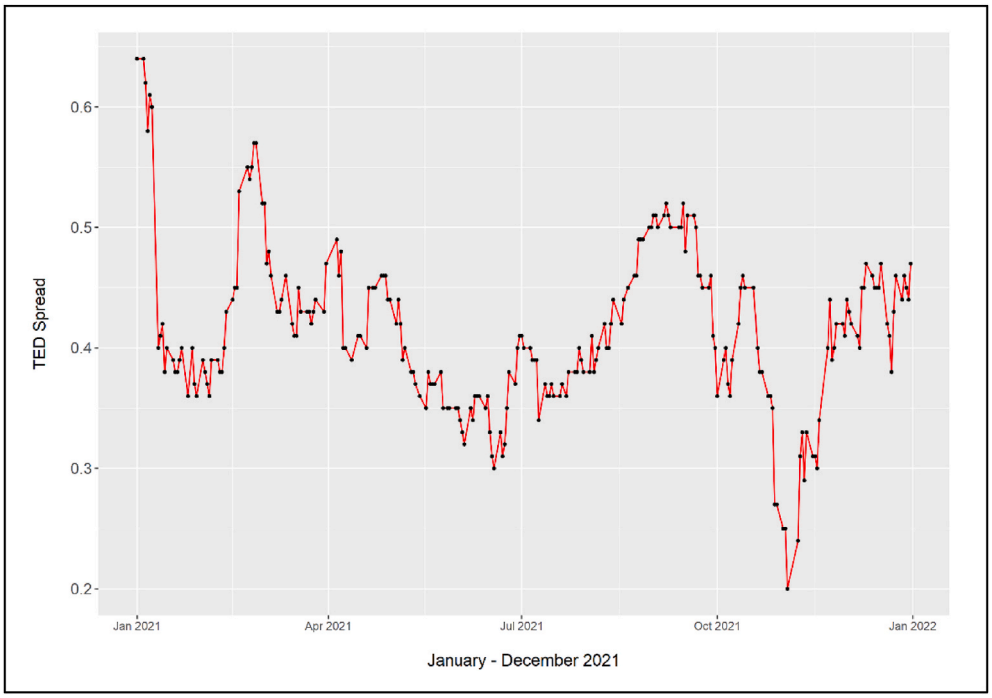

Fig. 6. Illustrates the volatility of the Indian TED Spread measure, an indicator of credit and economic risk. This measure was positively associated with stock prices (Fig. 7), as a surge in bond yields occurred alongside increases in stock prices.

stock markets and COVID-19 data was observed again, as discussed in the previous section. Meanwhile, the World model suggests that global stock markets were more strongly associated with COVID-19 data as 2021 came to a close, reacting positively to increases in vaccinations and negatively to increases in cases. Overall, mixed findings were observed in contrast to the previous period, suggesting that although COVID-19 growth and recovery remained significant long after vaccinations were introduced to the market, exceptions existed where these indicators of pandemic development became insignificant as time passed.

Arguably most significant from Table 5 is the changing significance of oil prices during this period. Oil became more negatively associated or remained negatively associated with stock markets in China, Germany, France, the USA, India, and World models. This change is strongly indicative of the evolving macroeconomic conditions present in the latter half of 2021, as fears of inflation and rising commodity markets consumed financial market news. (Boesler & Rockeman, 2021; Igan et al., 2022; World Bank, 2021). Not only this, but the looming possibility of the outbreak of war in Ukraine in late 2021 increased the likelihood of fuel shortages and supply constrictions on a global scale, putting upward pressure on commodity prices, thus explaining the negative association between oil prices and global stock markets observed throughout this period.

India and Japan present notable model changes in contrast to the previous period, whereby a significantly increased R^2 value was observed in India and a significantly decreased R^2 value was observed in Japan. For the case of India, it can be seen that the TED Spread coefficient, the spread between the 3-month Government Bond Yield and 3-month Interbank Funding Rate outlined in Section 3.2, was positively and strongly associated with index prices. Typically, this spread is seen as an indicator of credit, liquidity, and economic risk and is commonly seen to spike in times of crisis and uncertainty (Mayberger, 2014; Wang & Park, 2021). Therefore, the positive coefficient observed in this period is counterintuitive to traditional financial theory. However, the market dynamics in underlying government bonds throughout this period are likely responsible for this relationship. As Sircar (2021) found, India was undergoing near-record borrowing throughout 2021 to support the nation in battling the economic effects of the pandemic. With this, the government announced the opening of the $1.1 trillion bond market to retail investors amid a concurrent surge in 3-month bond yields throughout 2021 (Fig. 5). This was driven by rising inflation fears, surging oil prices, and growing consumer inflation indices month-on-month (ENS Economic Bureau, 2021). Alongside this announcement, the TED spread surged over 100% in late 2021 from as low as 0.2 to 0.47 (Fig. 6) as bond markets experienced volatility. Despite this, stock markets in India continued to surge in late 2021 (Fig. 7), independent of bond market activities and irrespective of rising inflation, thus explaining the positive relationship between the bond yields and stock prices observed during this period.

For the case of Japan, a significantly reduced R^2 value of 0.56 was observed, in contrast to the R^2 value of 0.89 observed in Table 4. The significance of the LIBOR-OIS spread was omitted from the final market model for this period, suggesting that fears of credit and liquidity risks were muted in the latter half of 2021. Additionally, the coefficients observed for both COVID-19 cases and vaccinations inverted, with a positive association between cases and stock prices and a negative association between vaccinations and stock prices. While this appears counterintuitive, the containment of the virus in Japan must be considered in this context. As shown in Fig. 8, new COVID-19 cases in 2021 peaked in August before the curve began to flatten significantly, with new cases becoming negligible by the end of the year. As such, during this period (July to December 2021), it can be suggested that measures of COVID-19 growth or recovery in a region with no active or uncontrollable outbreak became a moot point for financial markets, prompting the counterintuitive and inverse association observed in this period.

Overall, a reduction in explainable variance was observed for the latter half of 2021 across eight of the ten models, suggesting that the same factors which explained stock prices in early 2021 failed to do so to the same extent in the latter half of the year. Despite the regional explanations presented in this paper for the model variations observed during this period, several overarching macroeconomic risk factors also came to fruition within financial markets. These include the crackdown on trading of Chinese stocks on US exchanges (Li, 2021), the build-up of Russian troops on Ukrainian borders amid the expectation of war (Caldara et al., 2022), rising commodity prices amid fears of inflation, and finally, the confirmation and commencement of interest rate hikes in an effort to reduce these inflation measures (Federal Reserve, 2021). As the focus tilts away from COVID-19, it is now imperative for research to account for these new and emerging macroeconomic risk factors in an era of global political tension, rising inflation, and rising interest rates as the global economy moves on from the COVID-19 pandemic.

6. Conclusion and future research avenues

While the direction of causality between economic growth and stock markets is a contestable debate, it is well established that the real economy is heavily influenced by financial markets and vice versa. The implications of this relationship in the fallout and subsequent recovery from COVID-19 are imperative for policymakers, regulators, and stock market participants alike. This study examined the response of 10 major equity indices to the COVID-19 pandemic from January 2021 to December 2021. While most of the existing literature on this subject primarily examines the initial onset and negative impact of the pandemic, this study adopts a unique approach by investigating a period characterized by increasing positive sentiment during the implementation of global vaccination programs. During this period, there was a notable resurgence in virus growth, with case numbers and fatalities reaching their highest levels recorded in 2021. Thus, this study aimed to determine whether a positive COVID-19 indicator (total vaccinations) remained a significant market factor in the presence of a negative indicator (total cases) and a comprehensive set of market drivers as controls.

Our results provide practical implications and insights to governments, regulators, and financial market stakeholders. The price of oil was significant in both wave one and wave two, with several positive correlations observed, suggesting that as the price of oil rose (often seen as a proxy for inflation), so too did equity index prices. Our findings also illustrate the susceptibility of Chinese stock markets to fears of credit and liquidity risks, with increases in the LIBOR-OIS spread resulting in a decrease in equity index prices. As such, through further research, we intend to explore the novel policy responses, restrictive regulatory environment, and unique

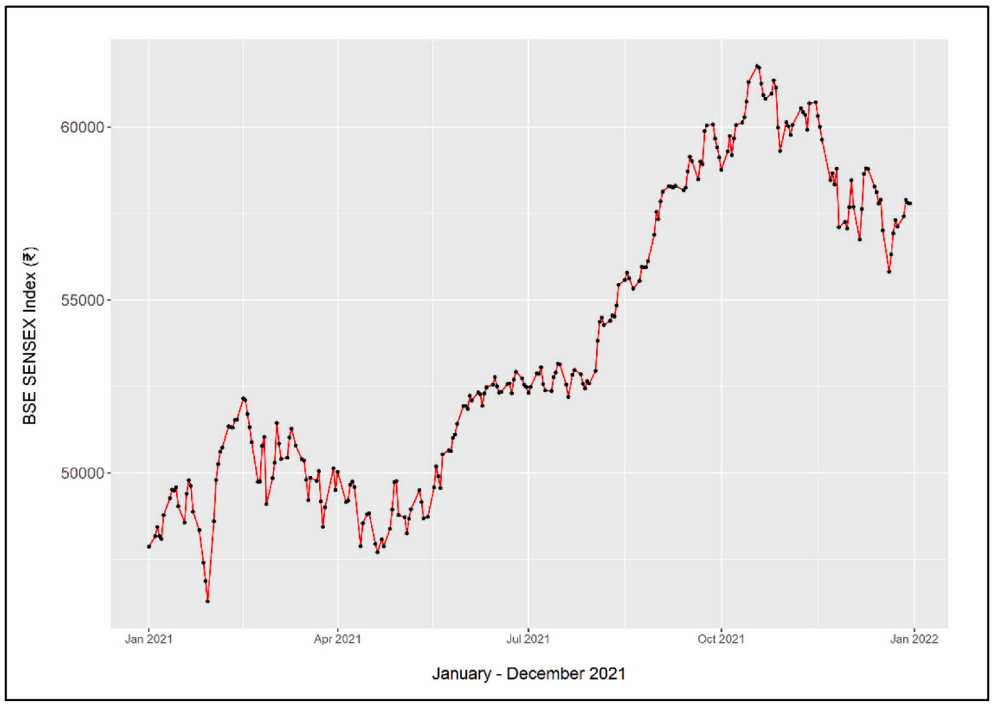

Fig. 7. Illustrates the BSE SENSEX Index representing the broader Indian Stock Market throughout 2021. A distinct rally in stock prices is evident, despite growing COVID-19 cases, surging government bond yields (Fig. 5), and TED Spread volatility (Fig. 6).

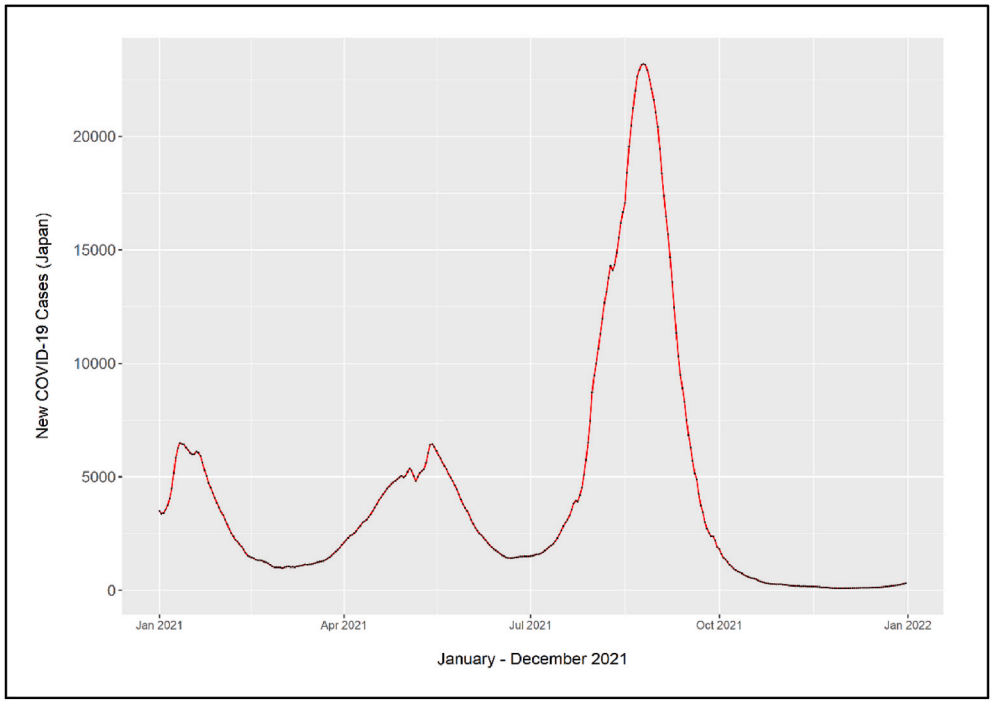

Fig. 8. Illustrates new cases of COVID-19 in Japan throughout 2021, highlighting a significant outbreak in mid-2021, peaking in August before tapering significantly. By year-end, new cases of COVID-19 were negligible, as the observed coefficients on both COVID-19 cases and vaccinations became inversed in this period (Table 5).

characteristics of the Chinese banking and stock market sector in the wake of COVID-19 to further shed light on the drivers and interconnectedness of financial systems in the face of unforeseen crises.

While traditional market variables remain significant in driving equity index prices, the sustaining impact of raw COVID-19 data on financial markets is essential to note. Developed countries with strong vaccination approval and uptake levels observe a positive association with equity index prices. However, India, an emerging market with high levels of vaccine hesitancy and low vaccine administration, did not observe a similar reaction. This is in line with Rouatbi et al. (2022), who found that the impact of vaccinations was more substantial for developed markets than for emerging ones during COVID-19. As a result, investors and traders in financial markets should monitor vaccine progress, approval, and administration metrics during future pandemics or comparative adversarial events to effectively hedge and diversify portfolios originating in different geographical regions. In addition to the asymmetric progression of vaccination developments, the asymmetric reaction of governments and policymakers should also be monitored by financial market stakeholders. Our results suggest that early interventions by the Chinese government and swift policy implementation by the People's Bank of China are attributable to a reduced significance level of COVID-19-related data on financial markets. Our findings suggest that in the event of future pandemics or periods of societal disruption, forceful but decisive policy measures may promote an increased long-run recovery effect, despite the potential for short-run adverse effects.

CRediT authorship contribution statement

Niall O'Donnell: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization. **Darren Shannon:** Validation, Writing – review & editing, Supervision, Project administration. **Barry Sheehan:** Validation, Writing – review & editing, Supervision, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. No funding was received for this work.

Data availability

I have shared access to a repository containing the source code used to gather the data within the manuscript.

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