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Research article

Emerging markets' response to COVID-19: Insights from arbitrages strategies

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ABSTRACT

Global capital markets are sensitive to extreme and physical events. This research explores the influence of COVID-19 on cross-border arbitrage strategies in emerging markets. Specifically, this study develops a novel cross-market pairs trading strategy centered on healthcare stocks, tailored for the unique dynamics of the emerging market environment. The feasibility of cross-border arbitrage strategies in emerging markets is demonstrated by comparing the performance of the strategy before and after the outbreak. Additionally, sensitivity analysis of the risk preference factors before and after the COVID-19 outbreak further supports this argument. These findings offer valuable insights for international investors seeking arbitrage between emerging and other markets and, effectively responding to global shocks.

1. Introduction

The impact of the COVID-19 pandemic on global financial markets, particularly emerging markets, has been extensively documented. Most scholars argue that the COVID-19 pandemic has profoundly impacted emerging markets, substantially declining equity returns and exacerbating market risks [1–3]. However, the increased volatility, driven by the global COVID-19 crisis, has not only heightened market risk in emerging markets but also generated additional opportunities for cross-border matching trades across different markets. This study investigates the impact of COVID-19 on cross-market arbitrage strategies in emerging markets, guiding for international investors to identify more arbitrage opportunities between emerging and other markets, mitigate investment risks, and respond effectively to global shocks.

Over the past two decades, emerging markets have experienced rapid growth and closer integration into the global markets. With the deepening of capital liberalization, entry barriers in emerging stock markets have consistently diminished over time. The influx of foreign capital into emerging capital markets has provided substantial funding support for pairs trading, enhanced market liquidity and capital activity in emerging markets, strengthened the connections with global markets, and promoted the development of global

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financial integration. Academic research and market practices have consistently demonstrated the advantages of emerging markets [4]. During the pandemic, emerging economies implemented loose monetary policies to alleviate the market uncertainties caused by public health emergencies. These policies have released market liquidity and reduced cross-market transaction costs, increasing cross-border arbitrage opportunities. They also boost international investor confidence and provide a conducive environment for cross-border pairs trading.

China and the United States, as representatives of emerging and developed markets, respectively, hold prominent positions globally due to their significant market scale and influence.[2] Their fluctuations and dynamics facilitate capital flows across markets, directly impacting other emerging economies. Furthermore, these nations exhibit significant variations in micro-market structures, encompassing regulatory frameworks, market participant structures, scale, maturity, and information transparency. For instance, China's stock market adheres to stricter regulations compared to the United States, where market freedom and transparency are emphasized. These distinctions contribute to price disparities and information delays, consequently fostering increased opportunities for arbitrage trading.

This study investigates the performance of cross-border arbitrage strategies in emerging markets during the COVID-19 pandemic. To mitigate interference from external factors, we adopt the method proposed in Ref. [5] to divide the entire sample into two periods. Our analysis focuses on the markets of China and the United States. Moreover, given the heterogeneous impact of the pandemic on various industries, we identify the healthcare sector with the highest market capitalization during the pandemic and consistently positive returns. This strategic focus aims to mitigate investment risk exposure effectively. We further conduct a comparative analysis of the sensitivity of risk preference factors to arbitrage trading strategies before and after the pandemic to assess the impact of market changes on arbitrage trading.

This study contributes to existing literature in several ways. First, we employ the cointegration theory for cross-border pairs trading in emerging markets, particularly amidst the global spread of COVID-19. This study provides new insights into the impact of COVID-19 from the perspective of cross-border pairs trading, offering strategic guidance for emerging markets to respond to sudden extreme events effectively. Second, unlike previous studies, which primarily focused on the feasibility of hedging healthcare sector investments across industries, we are trailblazing by targeting specific healthcare sectors for cross-market arbitrage investments. This emphasizes the long-term investment value of the healthcare industry in uncertain environments, providing a new perspective and understanding for the development of cross-market investment strategies. Moreover, it offers investors a broader range of investment options to mitigate risk exposure and pursue stable returns even in extreme conditions, thereby achieving dual objectives. Additionally, our expansion of pairs trading from a single market to cross-border markets broadens the scope of research related to pairs trading.

Our findings demonstrate that developing cross-market pair-trading strategies based on emerging markets' dynamic characteristics and structures can yield consistent positive returns. This strategy exhibits resilience even under conservative transaction cost. During the pandemic, the performance of the strategy remained stable and increased by approximately 7.46 % compared with pre-pandemic levels. Risk preference factors, such as the open and stop-loss parameters were selected to analyze the sensitivity of the cross-market arbitrage strategy performance to key trading parameters. These results further validate the effectiveness of cross-border trading strategies in emerging markets in response to unexpected event.

The remainder of this paper is structured as follows: Section 2 reviews relevant literature. Section 3 introduces the methods and models used in the study. Section 4 reports and discusses the data and empirical results. Finally, Section 5 summarizes the study with concluding remarks.

2. Literature review

At the end of 2019, the COVID-19 pandemic caused significant turbulence in the global economy. Compared to the global financial crisis of 2007–2008, researchers argue that the impact of the COVID-19 pandemic was more profound [6,7]. Traditional financial crises typically concentrate on the economic and financial sectors. In contrast the COVID-19 pandemic has brought about widespread disruptions across multiple facets of global society, encompassing the economy, transportation, healthcare, and beyond, all within a relatively short timeframe.

This study contributes to the literature on the impact of COVID-19 on emerging economies. Previous research has utilized a variety of models to explore the effects of COVID-19 on emerging markets, with a specific emphasis on stock market volatility. Baker, Bloom [8,9], Zaremba, Kizys [10], Zhang, Hu and Ji [11], Ashraf [12,13] argue that the pandemic's outbreak has triggered a global economic downturn, leading to pronounced volatility in the stock markets of emerging economies due to their high sensitivity. This volatility is further propagated across countries through a risk contagion mechanism, enhancing the interconnectedness between nations during extreme events [14]. Distinct from prior studies, this paper adopts a novel approach by analyzing the economic effects of COVID-19 on emerging markets through the lens of cross-border pairs trading. Compared to normal periods, the uncertainty shocks from extreme events prompt multinational investors to reallocate assets across different markets, seeking safer and more stable investment strategies to mitigate risks. Therefore, gaining a deeper understanding of the changes in cross-border arbitrage performance among emerging markets is crucial, as it will empower investors to adjust and optimize their investment strategies to effectively navigate global shocks.

Scholars examine the impact of the spread of the COVID-19 pandemic's on industries. Kayani, Aysan [15] observed that stock

[2] As of December 2023, the New York Stock Exchange held the top global position in market capitalization, standing at approximately $25.5647 trillion USD, followed by Nasdaq with around $23.4147 trillion USD. China's market, ranking third globally and first in Asia, had a market capitalization of approximately $10.8112 trillion USD.

return volatility increased during the COVID-19 pandemic, with spillover effects manifesting between different industries within specific markets. Additionally, there was heterogeneity in how various sectors reacted to the pandemic's shock. Baek, Mohanty and Glambosky [16], Baig, Butt [17], Mazur, Dang and Vega [18] found that industries such as tourism and leisure, real estate, and oil are on the brink of collapse due to the pandemic's repercussions. Conversely, the healthcare sector has attracted investor interest because of its exceptional performance [19–21]. Salisu, Akanni and Vo [22], using the VARMA–CCC–AGARCH model, identified significant bidirectional return spillover effects between the healthcare and tourism sectors during the pandemic.

Furthermore, they confirmed the efficacy of healthcare stocks in hedging against tourism stock-related risks. Al-Nassar, Yousaf and Makram [23] broadened the research scope by examining the sectors that were positively and negatively affected by the pandemic. Employing the DCC-GARCH model, they demonstrate increased volatility spillover effects between sectors during the COVID-19 pandemic. They also advocate including positively performing industries, such as healthcare, in stock investment portfolios as a hedge against risks. However, the arbitrage value of the healthcare sector under extreme conditions is rarely considered. Shleifer and Vishny [24] emphasize expertise in arbitrage trading. Focusing on a specific sector is advantageous as it enhances expertise and a deep understanding of that sector, facilitates the capture of more arbitrage opportunities, and mitigates the overall risk level of the investment portfolio. This strategic approach is pivotal for constructing cross-market pair-trading investment portfolios and, distinguishing our study from others.

This study is also related to a strand of literature on pairs trading. Pairs trading is currently the most classic statistical arbitrage strategy, with early research primarily focusing on the performance of the strategy in specific markets [25–29]. Gatev, Goetzmann and Rouwenhorst [30] were pioneers in applying the Distance Method (DM) to pair-trading strategies in the US market, a move that yielded significant financial gains. Further analysis extending the observation period to 2002 reaffirmed the strategy's robust profitability, primarily ascribed to addressing the disparities inherent in the "law of one price." Subsequent studies by Do and Faff [31,32] continued to leverage the DM, even as they factored into the impact of trading costs on strategy returns. Despite including variables such as commission fees, pairs trading continued to demonstrate profitability, albeit with diminishing margins. With the development of economic theory, Vidyamurthy [33], Burgess [34] introduced cointegration to identify long-term equilibrium relationships between different assets, enabling the construction of robust investment portfolios. Dunis and Shannon [35], Galenko, Popova and Popova [36] introduced a multivariate cointegration framework and designed trading strategies to track market indices and neutral investment strategies, that performed well in the market. This serves as proof of the feasibility of the cointegration methods. Hain, Hess and Uhrig-Homburg [37] extended multivariate cointegration to the European energy market and discovered excess returns that differ from simple momentum and reversal strategies, elucidating the profitability of cointegration trading in the European commodity market.

Additionally, Balladares, Ramos-Requena [38], Ramos-Requena, López-García [39], Ramos-Requena, Trinidad-Segovia and Sánchez-Granero [40]utilized the Hurst exponent to optimize stock pre-screening mechanisms, and their results confirmed the profitability of the improved strategies. Ramos-Requena, Trinidad-Segovia and Sánchez-Granero [41], diverged from conventional equal-weight allocation approaches in pairs trading by introducing various models aimed at optimizing the fund allocation for each stock. This methodology seeks to enhance the overall performance of pair-trading strategies. However, considering that this study focuses on the highly representative markets of China and the US as research subjects and their reactions under extreme uncertainty, we employ a more robust cointegration method and use the *E*-G test to construct cross-market stock pairs for two time-series variables. This distinguishes our study from other studies on cross-market investments.

3. Methodology

Drawing from the established research paradigm, the pair-trading strategy adopted in this study predominantly relies on the following steps.

First, we perform a correlation analysis of the assets, as the core of pairs trading is the degree of correlation between assets. At this stage, we focus on calculating the correlation coefficients between stocks to determine whether the price co-movements show a particular pattern of correlation. By analyzing the correlation coefficients, highly correlated stocks are identified so that potential arbitrage opportunities for these stock pairs can be considered. This helps investors screen potential pair-traded stocks and construct profitable portfolios.

We adopted the Pearson correlation coefficient to quantify the relationship between stocks. The coefficient spans from -1 to 1, denoting the strength and direction of the relationship between two variables. The Pearson correlation coefficients between the two variables were as follows:

$$\rho_{x,y} = \frac{\operatorname{cov}(X, Y)}{\sigma_x \sigma_y} = \frac{E\left[(X - \mu_x)\left(Y - \mu_y\right)\right]}{\sigma_x \sigma_y} \tag{1}$$

where, ρ is the Pearson's correlation coefficient. $\operatorname{cov}(X, Y)$ represents the covariance between the variables. μ_x and μ_y depict the anticipated values of the price series, and, σ_x and σ_y denote the standard deviations of the distinct series.

If a series of sample data for variables is available, estimating the covariance and standard deviations allows for the derivation of the sample correlation denoted by γ:

$$\gamma = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \overline{Y})^2}} \tag{2}$$

We assessed the strength of the correlation [42] grading scale for strength of correlation. Table 1 illustrates the relationship between the Pearson correlation coefficient and the degree of correlation.

A higher coefficient indicates that the price or return trends of the two assets are more consistent, suggesting potential arbitrage opportunities. Based on previous research experience, we choose (−1, −0.8) and (0.8, 1) as the criteria for determining the level of correlation between stocks.

Next, we identify the long-term equilibrium relationships among the selected pairs. Most studies adopt the DM for stock screening, aiming to identify statistical relationships between pairs, which mitigates reliance on economic models and, reduces the risk of erroneous estimations. With the development in economics and statistics, cointegration has gained widespread application in stock pairing owing to its capability to leverage long-term trends in asset prices, thereby constructing portfolios with long-term equilibrium relationships. Cointegration is essentially a measure of the long-term equilibrium relationships between variables and is, determined by testing whether linear combinations of variables with the same order of integration are stationary. According to the cointegration theory [43], deviations in asset portfolios from long-term equilibrium due to changes in asset prices are temporary. Over the long term, these pricing errors are rectified, leading to the convergence of the expected price differences. Cointegration tests are typically categorized into the Engle-Granger two-step test and the Johansen test [44]. When a model involves two or more variables, the Johansen test, based on the VAR model, is commonly used to examine the relationships between multivariate variables [45]. Scholars such as Ti and, Dai [46] also enhanced pair-trading methods using this approach. Extreme environmental uncertainty affects capital markets across countries. Referring to China and the United States, the world's two most influential economies, we employ the Engle-Granger cointegration test to verify the long-term equilibrium relationship between their respective capital markets. This verification allows us to construct a pair-trading portfolio. By adopting this methodology, we can adeptly mitigate non-convergence risks, even amidst the tumult of extreme event effects. In contrast to alternative approaches, cointegration enables the identification of stock pairs possessing enduring value under uncertain circumstances, allowing the precise capture of trading signals to determine optimal entry and exit timings. The resulting excess returns demonstrate resilience to fluctuations in the sensitivity factors.

The Engel Granger test is as follows:

$$P_t^1 = a_0 + a_1 P_t^2 + \varepsilon_t \tag{3}$$

Where P_t^1 is the historical price of the first paired stock, P_t^2 denotes the past price of the second stock in the pair, a_0 represents the average, a_1 represents the co-integration coefficient, and ε_t represents the residual.

The Ordinary Least Squares (OLS) technique is used to estimate α_0 and α_1 , generating residuals for the OLS regression. Subsequently, the stationarity of the residual is examined to ensure model validity. To test the stationarity of the deviation, we employ the widely used Augmented Dickey-Fuller (ADF) test [47], designed to determine the existence of a unit root:

$$\triangle P_t = c + \gamma t + \omega P_{t-1} + \sum_{j=1}^{n-1} \varphi_j \triangle P_{t-j} + \varepsilon_t \tag{4}$$

n denotes the lag order, γt signifies the time trend term, c represents a constant term, and ε_t denotes the error term.

To assess the presence of a unit root in the spread, we regress Eq. (4)

Null hypothesis is H0: $\omega = 0$, and the alternative hypothesis is H1: $\omega \leq 0$.

The cointegration coefficient and its corresponding t-statistic are as follows:

$$ADF_t = \frac{\widehat{\omega}}{\sigma(\widehat{\omega})} \tag{5}$$

Table 1
Pearson's correlation coefficient with the degree of correlation of variables.

Pearson correlation coefficient	Degree of variable correlation
0.8–1	Extremely Strong
0.6–0.8	Strong
0.4–0.6	Moderate
0.2–0.4	Weak
0~0.2	Irrelevance
−0.2~0	Irrelevance
−0.4~-0.2	Weak
−0.6~-0.4	Moderate
−0.8~-0.6	Strong
−1~-0.8	Extremely Strong

$$\sigma(\widehat{\omega}) = \sqrt{\frac{\sum_{i=1}^{n} (\triangle p_{ti} - \triangle p_t)^2}{(n-2)\sum_{i=2}^{n}\left(p_{i(t-1)} - \overline{p_{i(t-1)}}\right)^2}} \tag{6}$$

$\widehat{\omega}$ represents the estimated cointegration coefficient, and $\sigma(\widehat{\omega})$ is the standard deviation from the regression. If the t-statistics obtained from Eq. (5) is below the ADF test threshold, we reject the null hypothesis H0: $\omega = 0$, confirming the stationarity of the residual sequence in Eq. (1) and establish the cointegration relationship in the prices of the two stocks.

Furthermore, given the sensitivity of the ADF test to sample size, heteroscedasticity, and serial correlation, we conduct a PP test [48] as a supplement. The Phillips-Perron test (PP test) is a statistical method used to test for unit roots (non-stationarity) in time-series data, representing an improvement over the traditional Augmented Dickey-Fuller (ADF) test. The basic steps of the PP test are as follows:

$$\triangle Y_t = a + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p-1} \delta_i \triangle Y_{t-i} + \varepsilon_t \tag{7}$$

Where $\triangle Y_t$ is the first difference in the time series data. α is the intercept term; γ is the autoregressive coefficient, representing the impact of Y_{t-1} on $\triangle Y_t$; and ε_t is the error term, representing the unexplained random part of the model.

First, we constructed an autoregressive model (as shown in Eq. (7)), including the possible lagged term $\triangle Y_{t-i}$.Next, the residuals were calculated by fitting the estimated AR (Autoregressive) model to the data to, obtain the ε_t.Finally, a unit root test was conducted using ε_t to determine whether the residual sequence was stationary.

Applying the Phillips-Perron (PP) test to cross-market stock pairs and, rejecting the null hypothesis at the 5 % confidence level further demonstrates that the residual sequence of Eq. (1) is stationary, which enhances the robustness and accuracy of the test results.

Finally, appropriate trading signals are established based on paired stocks. After conducting cointegration tests, we obtain the cointegration vector for the relevant stock pairs and then construct the arbitrage portfolio positions based on the long-term equilibrium relationship. When the spread between related stocks deviates significantly from the equilibrium range and triggers a trading signal, the portfolio is built and traded according to the percentage of the arbitrage portfolio position. The steps were as follows:

First, we calculated the spread sequence of the pairs, along with their mean and standard deviation, based on Eq. (3).

$$\varepsilon_t = P_t^1 - a_1 P_t^2 - a_0 \tag{8}$$

Next, the opening and stop-loss positions are established using the average and variability of the spread series.

Opening and closing position:

$$\varepsilon_t = (\mu - c_2\sigma, \mu - c_1\sigma) \cup (\mu + c_1\sigma, \mu + c_2\sigma) \tag{9}$$

stop-loss position:

$$\varepsilon_t \in (-\infty, \mu + c_2\sigma) \cup (\mu + c_2\sigma, +\infty) \tag{10}$$

where μ represents the average spread, σ is the standard deviation, and c signifies the factor influenced by investors risk preferences. More precisely, the established criteria for this study's opening and closing positions are predicated on a range of thresholds for the spread series, where $\mu - c_1\sigma$ and $\mu + c_1\sigma$ represent the two trading thresholds.

In a typical trading range, positions are initiated during $\varepsilon_t < \mu - c_1\sigma$. In this case, if the short-term projection indicates an upward movement in stock 1 accompanied by a decline in stock 2, investors choose to buy stock 1 and sell stock 2. Conversely, when $\varepsilon_t > \mu + c_1\sigma$, if the valuation of stock 1 is anticipated to decline and that of stock 2 is expected to rise, the arbitrageur will shorten stock 1 and go

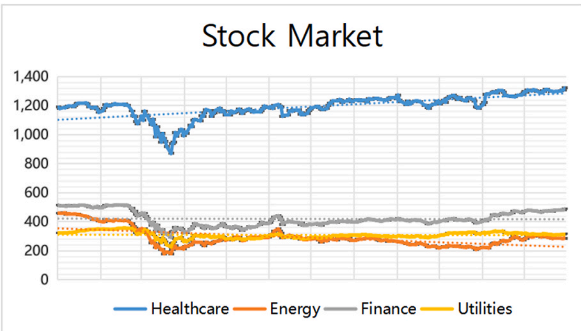

Fig. 1. Changes in different industries during the pandemic
Note: The X-axis represents each day of the year 2020, the Y-axis represents market prices, denoted in US dollars.

long on stock 2. The parameters $\mu - c_2\sigma$ and $\mu + c_2\sigma$ represent two stop-loss lines that, mandate closure if the spread sequence breaches these lines and consistently deviates from the stop-loss conditions.

4. Data and discussion

4.1. Data description and modeling

Given the outstanding performance of daily data in pair-trading strategies [49], this study uses daily stock prices to capture potential market interactions. The objective is to explore the market performance of cross-market arbitrage strategies between emerging and other markets under the impact of COVID-19. We conducted a comparative analysis of market performance among several industries significantly affected by the pandemic, as illustrated in Fig. 1. The findings clearly indicate that the healthcare sector outperformed other industries in terms of overall market performance during the outbreak of the pandemic. Consequently, we strategically prioritize investments in healthcare to achieve higher profits and maintain stability. Considering factors such as market capitalization and index compilation methods, we selected the CSI Healthcare Index and the S&P 500 Healthcare Index as the stock pool for executing pairs trading, totaling 136 stocks. The daily closing prices of the constituents of the two indices are sourced from the Wind Database and Yahoo Finance. To ensure temporal consistency for comparative analysis, the study used December 31, 2019, as a pivotal date (the day when the Wuhan Municipal Health Commission reported the first group of pneumonia cases in Wuhan, Hubei Province, ultimately confirming the novel coronavirus). The samples were divided into two sub-samples based on the pre and post-outbreak periods. This division facilitates the examination whether COVID-19 affects cross-market pair-trading strategies. The two sub-samples comprised the daily closing prices in the Chinese and American markets for the full years of 2018 and 2020, respectively. We followed the approach outlined by Andrade and Ferroni [50] and divided the implementation of cross-market trading strategies into two phases. The first phase covers the periods from January 1, 2018, to June 30, 2018, and from January 1, 2020, to June 30, 2020, and is used to determine paired stocks, construct cross-border arbitrage strategies for emerging markets, and optimize parameters. The second phase involves a six-month trading period during which the performance of the "optimal" investment portfolio is evaluated using profitability indicators, following the standard practice in the literature. Considering that market closures on weekends and holidays may lead to missing data and disrupt the continuity of stock price series, thus affecting subsequent empirical analysis, this study uses the moving average method to fill in missing data and applies pre-adjustment to stock prices to ensure the continuity and authenticity of price trends.

Additionally, considering the difference in trading hours between China and the United States, understanding the operating hours of one market relative to the other is crucial. Table 2 represents the opening and closing times of stock exchanges in China and US. Following the practices outlined in Ref. [51], we made some modifications in data processing, including appropriate lag values and logarithmic transformation of all stock price series, where the closing price at Beijing time on day t+1 is considered the closing price of the US stock market on day t. Tables 3 and 4 document the basic statistical information of selected stocks in the stock pool before and after the outbreak. Fig. 2 illustrates the correlation analysis of stock prices between selected Chinese and American markets before and after the outbreak. By comparing the overall correlation coefficients, we observe an increase in the correlation of healthcare sector stocks between China and the United States after the outbreak, indicating strengthened connections among the global stock markets during extreme events. This finding is consistent with that in Ref. [36], implying potential arbitrage opportunities.

In the benchmark scenario, the risk preference parameter c_1 in the trading signal was set to 1.5, while the risk preference parameter c_2 was set to 2.5. This follows the methodology outlined in Ref. [52], which consider the variability in commission fees across different investment institutions in real trading scenarios, where transaction costs are set at 15 basis points.[3] To account for potential fluctuations in exchange rates between foreign and domestic currencies that may impact foreign investments denominated in the domestic currency, all valuations are standardized in US dollars, and hedging strategies[4] as described in Ref. [53], are employed to mitigate exchange rate risk.

4.2. Model backtesting and trading performance

We select two trading periods, specifically the six-month periods from July 1, 2018, to December 31, 2018, and from July 1, 2020, to December 31, 2020, as the pre- and post-outbreak periods, respectively. Figs. 3 and 4 graphically illustrate the back testing framework of the trading periods. During these periods, we collect the daily closing prices of Chinese and American healthcare index stocks and construct arbitrage portfolios based on the trading rules set during the formation period. Subsequently, we conducted a detailed analysis of the return performance.

Table 5 and Table 6 present the cross-market stock pairs between emerging markets and other markets using the Engel-Granger test before and after the outbreak. This finding demonstrates the existence of long-term equilibrium relationships between stocks in different markets. Additionally, these tables provide detailed reports on the returns generated by arbitrage portfolios using the cross-market pair-trading strategy designed in this study.

Specifically, in Tables 5 and 6, all stock pairs passed the ADF and PP tests, rejecting the null hypothesis of the unit-roots at the 5 %

[3] Basis point (bps) is a financial measurement unit commonly used to indicate the magnitude of changes in financial indicators such as interest rates, bond yields, exchange rates, and so forth. One basis point is equal to one hundredth of a percent, or 0.01 %, often denoted as "bps."

[4] Assuming that hedging costs are lower than expected exchange rate fluctuations, currency risks can be hedged using options.

Table 2
Opening and closing times of major stock exchanges in China and US.

Stock market	Location	Local time	Time zone
China (SSE)	Shanghai	9:30–15:00	UTC+8
China (SZSE)	Shenzhen	9:30–15:00	UTC+8
Hongkong (HKEX)	Hong Kong	9:30–16:00	UTC+8
USA (NYSE)	New York	9:30–16:00	UTC-5
USA (NASDAQ)	New York	9:30–16:00	UTC-5

Note: UTC represents Coodinated Universal Time.

Table 3
Brief description of historical stock data for China and USA before the COVID-19[a].

Market	China			USA		
	Ticker	Average volume	Average price	Ticker	Average volume	Average price
	AEYK	12074079.42	33.72	ABMD	640938.52	340.16
	WWSW	2107490.737	43.14	HUM	809774.4	290.58
	ZFSW	14052143.92	39.52	SYK	1343598.4	157.11
	WSSW	14284628.67	20.12	BAX	3,326,296	64.53
	PZH	5525580.16	92.26	UNH	3297482.4	229.56
	RFYY	12116103.84	13.5	TMO	1499324.4	218.92
	TGYY	5104949.56	49.76	TFX	305,118	254.61
	TCYL	4117217.98	46.3	STE	386,722	99.1
	JZT	3394386.21	16.63	ISRG	2435125.2	159.9
	JLAD	6208280.21	18.31	IQV	1293246.4	110.56

[a] The temporal coverage spans from January 1, 2018, to December 31, 2018. The ticker of a Chinese stock is composed of the first letter of each stock's name.

Table 4
Brief description of historical stock data for China and USA after the COVID-19[a].

Market	China			USA		
	Ticker	Average volume	Average price	Ticker	Average volume	Average price
	CCGX	5378231.84	345.69	ABMD	519663.88	233.17
	KLY	2653830.55	154.49	BI0	226590.87	471.74
	PZH	4605790.19	180.23	TMO	1674932.14	380.73
	RFYY	19256867.7	26.16	WST	575892.86	222.75
	TGYY	7498378.53	97.15	HUM	1015089.29	374.09
	WWSW	4597870.64	56.03	SYK	1614357.94	192.75
	TCYL	3213903.91	164.59	BAX	3132088.89	79.35
	JZT	10651289.24	17.56	STE	555766.27	157.5
	JLAD	13987454.93	16.68	TFX	249408.73	353
	ZFSW	16663473.31	107.3	ISRG	2171648.81	208.88

[a] The temporal coverage spans from January 1, 2020, to December 31, 2020. The ticker of a Chinese stock is composed of the first letter of each stock's name.

significance level. This finding indicates the presence of long-term equilibrium relationships between stocks in different markets. Furthermore, the cointegration coefficients obtained at the 5 % significance level represent the position ratios of the stock pairs. Taking the pre-outbreak stock pair ABMD and AAYK as an example, the cointegration coefficient was 0.5780. In simple terms, this means that the composition of the pairs arbitrage portfolio could be long position in AAYK and 0.5780 short positions in ABMD, or one short position in AAYK and 0.5780 long positions in ABMD.

The performances of various cross-market pair-trading portfolios were compared before and after the COVID-19 pandemic. Despite the pandemic's significant impact on global stock markets, there is no negative impact on the performance of cross-border arbitrage strategies between emerging and other markets. Figs. 5–13 illustrate the specific performances of the strategies before and after the pandemic. The cross-market pairs trading strategy within the healthcare sector, spanning emerging markets and other markets, yielded annualized return of 9.62 %, 37.19 %, 31.09 %, and 30.82 %, respectively, during normal periods, culminating in a cumulative annualized return of 108.72 %. After the pandemic, the cumulative annualized returns increased from 31.08 % to 139.80 %.

Similarly, an increase in the win rate, as a quantitative indicator indicates that more trades was profitable after the pandemic, thus increasing the strategy's effectiveness of the strategy. This result may be due to the increased market uncertainty and volatility caused by the global pandemic, leading to wider spreads in related stock prices and more frequent deviations from their equilibrium prices, thus providing more arbitrage opportunities for cross-market pairs trading. The Sharpe ratio measures the relationship between portfolio or asset returns and risk. After the pandemic outbreak, the Sharpe ratio of cross-border investment portfolios decreased

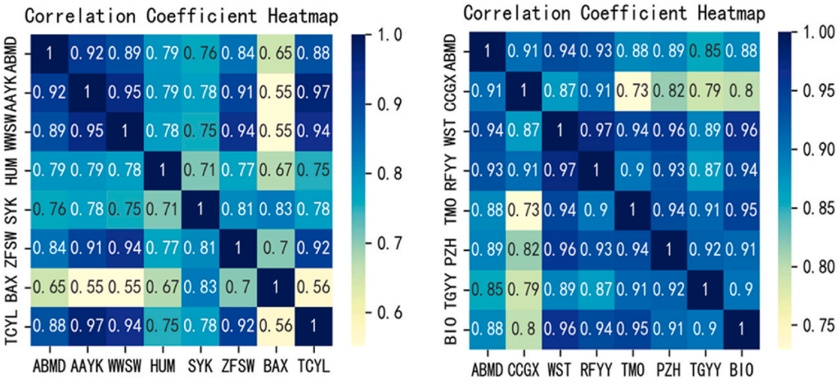

Fig. 2. Stock correlation heatmap pre-covid-19 and post-covid-19.

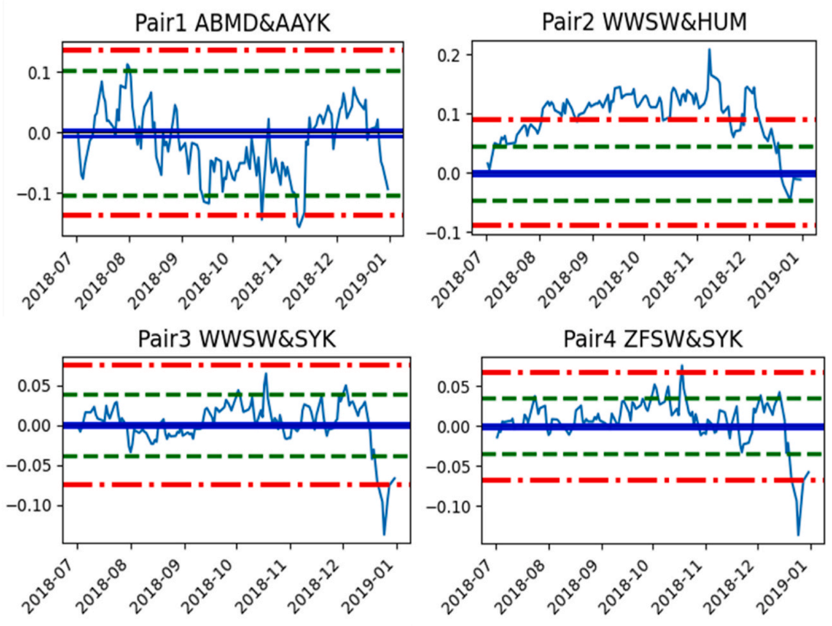

Fig. 3. Back-testing framework before COVID-19.

compared to before the pandemic. Fig. 13 shows an overall downward trend, implying an increase in market volatility. Furthermore, comparing the maximum drawdown of pairs trading before and after the pandemic reveal a cumulative increase of 13 % in the maximum drawdown rate after the pandemic, further confirming the impact of increased market volatility on portfolio risk.

The positive feedback from the cross-border arbitrage strategy in emerging markets under extreme shocks clearly demonstrates its market neutrality and relative independence, especially when facing sudden public events. This differs from previous studies on the negative impact of the COVID-19 pandemic on emerging markets [54]. Our research has ignited international investors' interest in exploring additional cross-border arbitrage opportunities in emerging markets to attain a more diversified investment portfolios. By efficiently allocating funds across markets and asset classes, investors can reduce the impact of specific market shocks on their portfolios, minimizing uncertainty and volatility's negative effects. Additionally, this study offers a fresh perspective on the feasibility of cross-border arbitrage for investment in the healthcare sector.

In addition to the impact of exogenous shock factors, changes in trading parameters, including, but not limited to, risk preference factors, model backtesting days, and transaction costs, may affect the returns of pairs trading and thus influence the applicability of trading strategies. Therefore, we conducted a sensitivity analysis of the model parameters to assess the impact of internal factors on the performance of trading strategies.

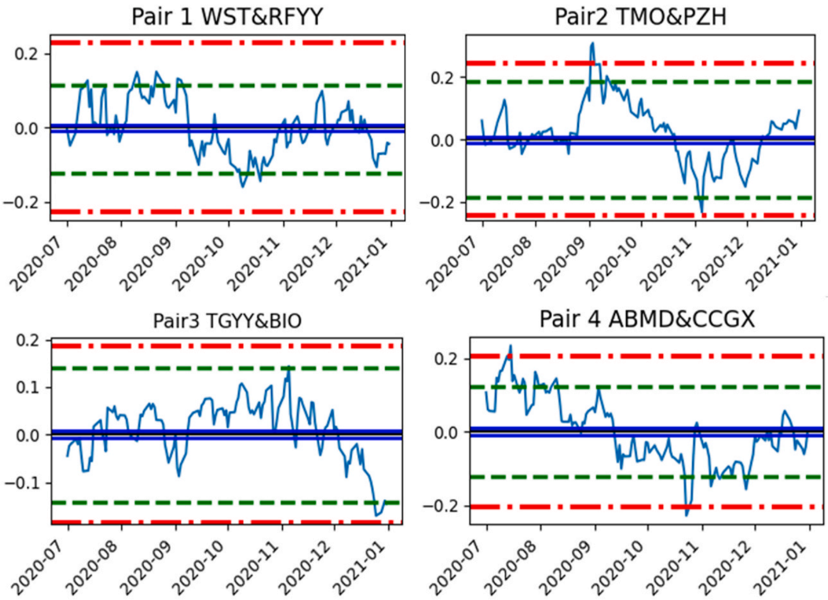

Fig. 4. Back-testing framework after COVID-19.

Table 5
Selected cross-market pairs before the outbreak.

Stock 1	Stock2	Coefficient	Annualized yield (%)	Sharp ratio (%)	Maximum drawdown (%)	Win rate (%)
ABMD	AAYK	0.5780***	9.62	1.45	0.06	0.50
WWSW	HUM	0.2053***	37.19	1.40	0.02	0.50
WWSW	SYK	0.1590***	31.09	1.41	0.01	0.43
ZFSW	SYK	0.1593***	30.82	1.40	0.03	0.43
Total			108.72	5.66	0.13	1.86

Table 6
Selected cross-market pairs after the outbreak.

Stock 1	Stock2	Coefficient	Annualized yield (%)	Sharp ratio (%)	Maximum drawdown (%)	Win rate (%)
WST	RFYY	1.3775***	17.35	1.40	0.04	0.40
TMO	PZH	1.5686***	35.36	1.41	0.09	0.50
TGYY	BIO	0.6553***	46.04	1.41	0.05	0.50
ABMD	CCGX	0.8494***	41.05	1.40	0.07	0.50
Total			139.80	5.62	0.26	1.90

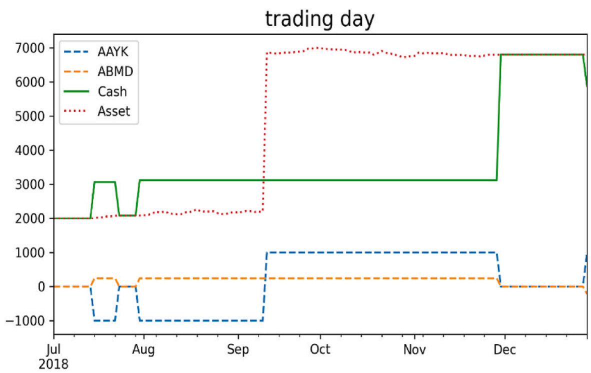

Fig. 5. Performance evaluation on AAYK&ABMD before COVID-19.

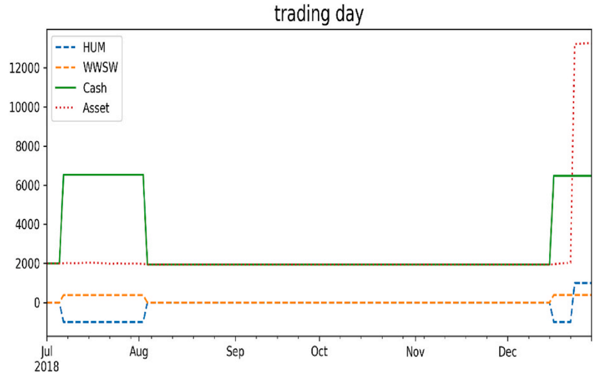

Fig. 6. Performance evaluation on WWSW&HUM before COVID-19.

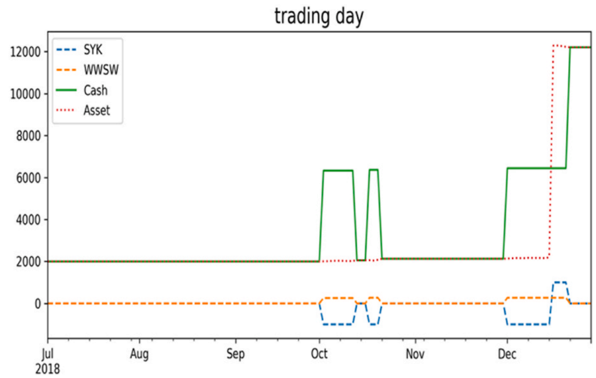

Fig. 7. Performance evaluation on WWSW&SYK before COVID-19.

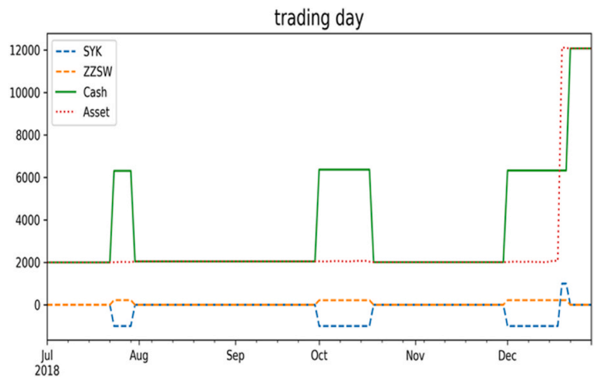

Fig. 8. Performance evaluation on ZZSW&SYK before COVID-19.

4.3. Sensitivity analysis

In this section, we focus on the risk preference factor as a critical parameter and conduct a sensitivity analysis of the returns on cross-border arbitrage portfolios between emerging markets and other markets before and after the pandemic. By examining the influence of the risk preference factor on the returns of pairs trading, this analysis facilitates the ongoing adjustment and enhancement of pairs trading strategies, allowing for more adaptable responses to market fluctuations and, consequently, more efficacious returns. In our evaluation, we employ the Sharpe ratio and annualized returns as quantitative indicators to gauge the performance of pair-trading markets, in line with the methodology outlined in Ref. [54]. This approach gives investors a holistic view of strategy performance by considering risks and returns, thereby supporting improved decision-making processes.

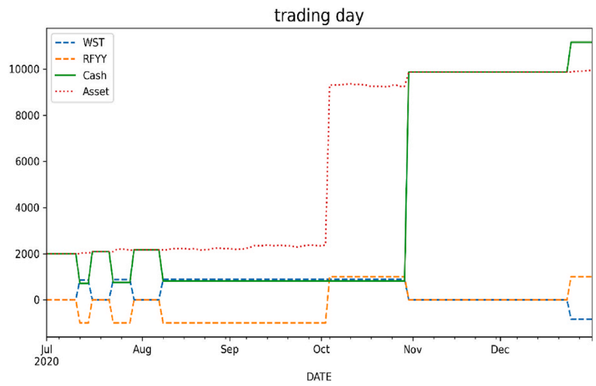

Fig. 9. Performance evaluation on WST&RFYY after COVID-19.

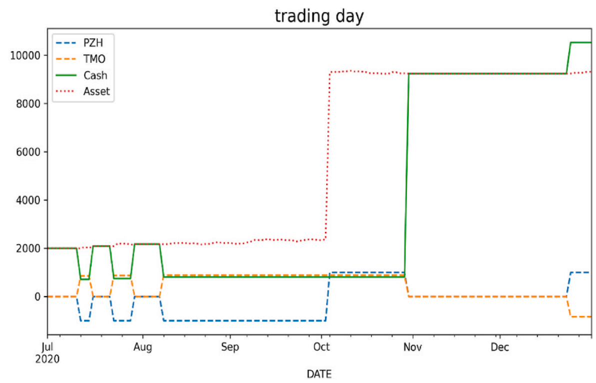

Fig. 10. Performance evaluation on TMO&PZH after COVID-19.

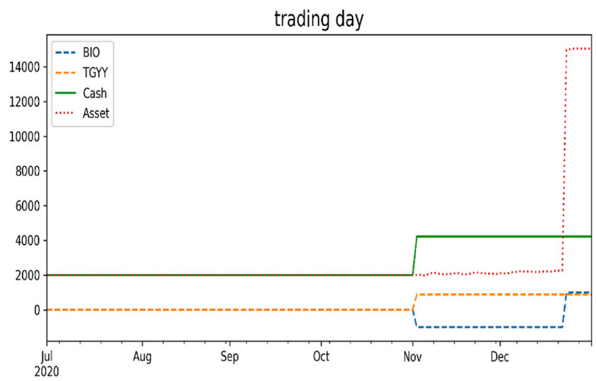

Fig. 11. Performance evaluation on TGYY&BIO after COVID-19.

4.3.1. Sensitivity analysis of risk preference factor before COVID-19

The performance of pairs trading strategies between emerging markets and other markets under varying risk preference factors c_1 is illustrated in Fig. 14. The impact of the risk preference factor on the annualized returns and Sharpe ratio of this cross-border arbitrage strategy is nonlinear. For pair1, the portfolio performance peaks when the risk preference factor reaches 1.3. Pair2 and pair3 exhibit peak Sharpe ratios and annualized returns of 1.1. The optimal arbitrage trading performance for Pair2 initially appears at a risk preference factor of 1.2, extends to 1.5, and then sharply declines to a negative territory. In contrast, the performance of pair4 remains negative until 1.5, then sharply increases to generate maximum returns. Performance of pair3, comparatively, exhibits milder fluctuations. After peaking at 1.1, it shows a fluctuating downward trend but maintains positive returns, making it suitable for investors seeking relatively stable investments.

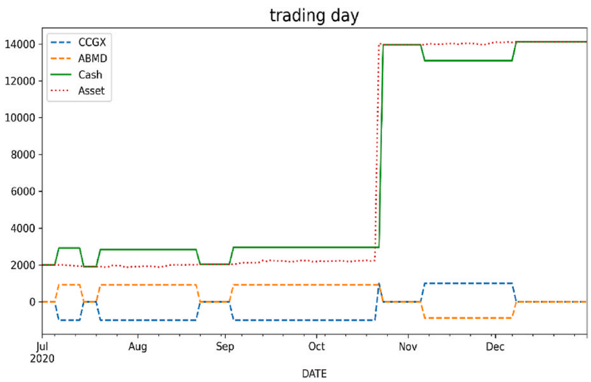

Fig. 12. Performance evaluation on ABMD&CCGX after COVID-19.

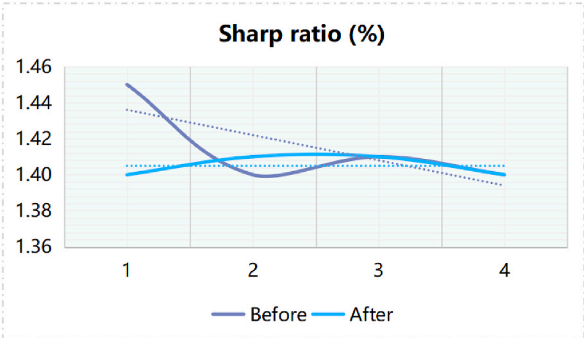

Fig. 13. Overall trend of Sharpe Ratio during pandemic outbreak.

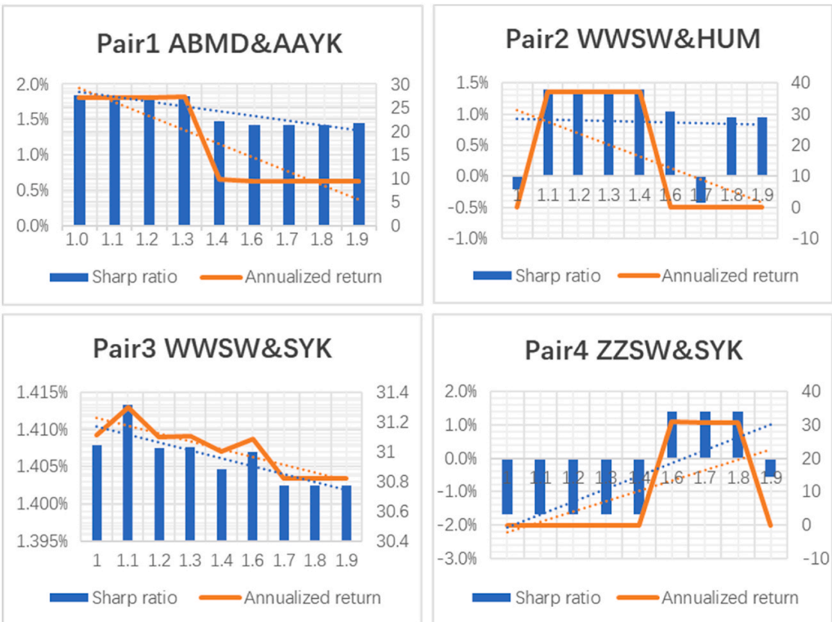

Fig. 14. Performance of pairs trading strategies under varying risk preference factors before COVID-19.

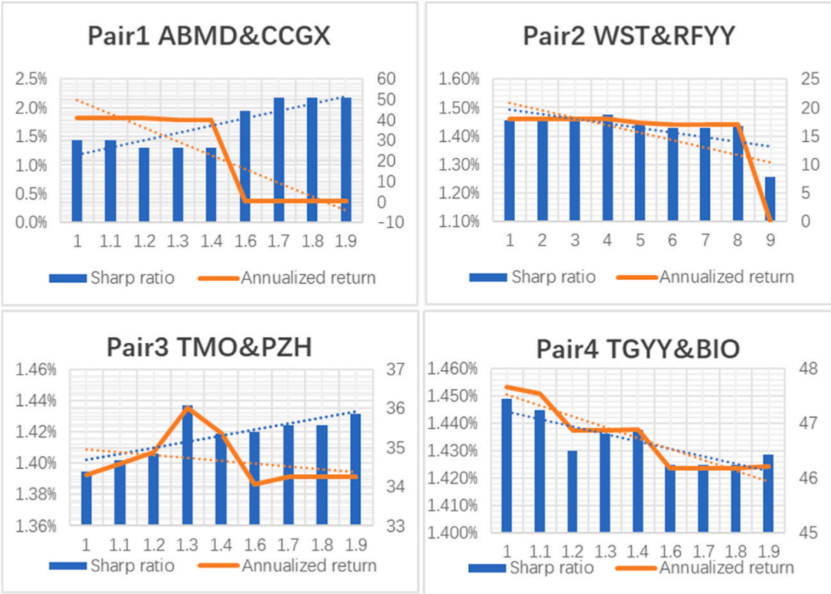

Fig. 15. Performance of pairs trading strategies under varying risk preference factors after COVID-19.

4.3.2. Sensitivity analysis of risk preference factor after COVID-19

Fig. 15 illustrates how the performance of cross-border pairs trading strategies between emerging markets and other markets changes with the variation in the risk preference factors c_1 after the pandemic outbreak. Unlike in normal periods, all portfolios exhibit sustained positive returns regardless of investors' risk preferences. This phenomenon contrasts sharply with the negative returns observed during normal periods as the risk preference levels change. The outbreak and spread of COVID-19 have significantly impacted global capital markets. However, despite changes in investor sentiment and risk-tolerance levels, cross-border pair-trading strategies based on emerging markets continue to generate sustained positive returns. This clearly demonstrates that such strategies are effective and reliable in coping with large-scale global shocks, making them independent and dependable amid such uncertainties.

4.3.3. Sensitivity analysis of stop-loss factor before COVID-19

Fig. 16 illustrates how the performance of the cross-market pair-trading strategies was affected by c_2 before the outbreak of the pandemic. It can be observed from the image that different stop-loss factors have varying impacts on the annualized returns and Sharpe

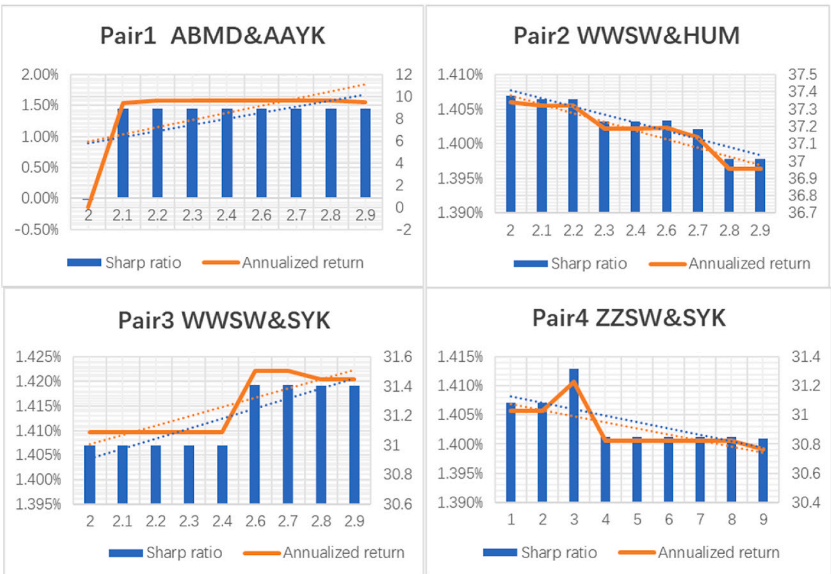

Fig. 16. Performance of pairs trading strategies under varying stop-loss factors before COVID-19.

ratios. For pair1, the strategy returns and Sharpe ratio reach their peak at $c_2 = 2.1$ after transitioning from negative to positive; similarly, pair3 and pair4 show a declining trend after reaching maximum returns at $c_2 = 2.6$ and $c_2 = 2.2$, respectively. On the other hand, for pair2, as the stop-loss factor continues to increase, both the overall strategy returns and the Sharpe ratio decline.

4.3.4. Sensitivity analysis of stop-loss factor after COVID-19

Fig. 17 shows the development trend of the portfolio performance under different stop-loss factors conditions following the outbreak of the pandemic. Pair1 and pair3 both reach their peak annualized returns and Sharpe ratios at $c_2 = 2.3$, while pair4 achieves its maximum returns at $c_2 = 2.2$, followed by a rapid decline. In contrast, the performance of pair2 has been consistently rising, especially when the stop-loss factor exceeds 2.8, with an accelerated growth rate. Overall, regardless of the changes in the stop-loss factor, the overall returns of this cross-market investment strategy increased after the pandemic, providing strong evidence of its effectiveness.

5. Conclusions and policy implications

This study employs a two-stage cointegration method based on healthcare sector stocks to construct cross-market pair-trading strategies between emerging markets and other markets, and examines the impact of the Covid-19 pandemic as an unexpected global shock on statistical arbitrage between emerging markets and other markets. The research indicates that cross-market pair-trading strategies between emerging markets and other markets exhibit stable arbitrage returns under the global pandemic shock. Compared with normal periods, the excess returns of this cross-market pairs trading strategy increased by 31.08 %, highlighting its stability and feasibility. This provides multinational investors an effective and novel approach to reduce uncertainty risk and protect their expected returns. Importantly, this study is the first to demonstrate the value of healthcare-sector stocks as a long-term sustainable investment tool from the perspective of cross-border arbitrage in emerging markets.

Additionally, a sensitivity analysis is conducted on the impact of risk preference factors on cross-market relative value arbitrage strategies in emerging markets before and after the pandemic. The study shows that, the impact of risk preference factors on pair-trading strategies is stable and positive post-pandemic. With appropriate parameter adjustments, all cross-border arbitrage portfolios based on emerging markets demonstrate optimal excess returns, showing the effectiveness and adaptability of this pair-trading strategy in response to global shocks, which is consistent with the findings of [55].

In conclusion, this study comprehensively examined the stability and effectiveness of cross-border arbitrage strategies between emerging and other markets during the COVID-19 pandemic. By examining the performance of an emerging markets-based cross-border arbitrage strategy in the presence of unexpected external shocks, we confirm its stability as an effective financial tool for emerging markets to cope with global shocks. This study contributes to a theoretically rich understanding of the influence of COVID-19 on emerging markets and provides a practical investment strategy for dealing with potential global shocks in the era following the pandemic.

Constructing portfolios from a combination of risk and return perspectives is critical for international investors facing uncertain global shocks. Emerging markets may offer more relative value opportunities than other markets during periods of high volatility. This study captures this potential values promptly by implementing a cross-border relative value-arbitrage strategy based on emerging markets. Diversification reduces risk while generating excess returns. Therefore, international investors can prioritize optimizing the risk and return characteristics of their overall portfolios by considering this emerging market's cross-border arbitrage strategy.

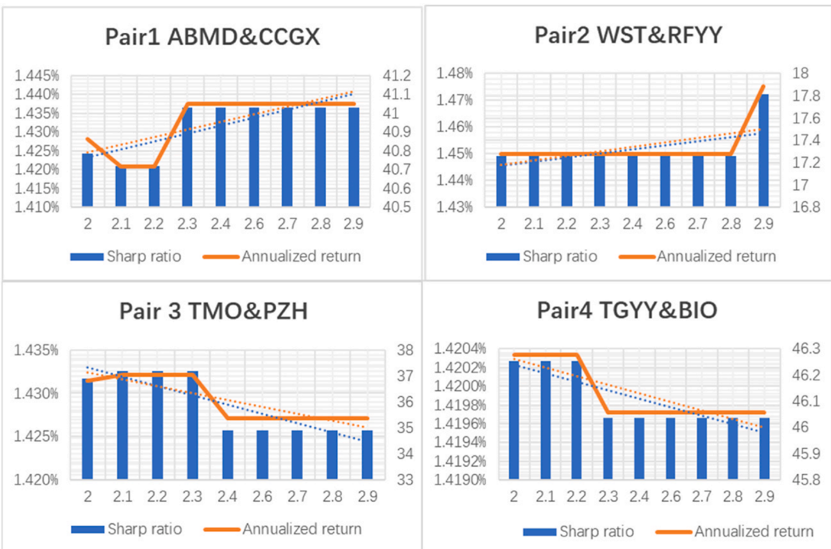

Fig. 17. Performance of pairs trading strategies under varying stop-loss factors after COVID-19.

Increased investment in this strategy facilitates diversification and, promotes cross-border capital flow and global financial integration.

This study also substantiates the sustainable investment attributes of healthcare stocks. Investors may consider incorporating these stocks into their portfolios to mitigate risk exposure, secure anticipated yields, and ensure the long-term sustainability of investments.

For regulators and policymakers in emerging markets, these findings indicate that cross-border arbitrage strategies, yielded positive returns during the health crisis, when applied to emerging markets. This underscores their resilience in scenarios characterized by global shocks. To further enhance market resilience in the face of future global challenges, policymakers should encourage and support the stability of market mechanisms to ensure that markets are more flexible and responsive. These findings provide valuable guidance for regulatory policies and market standards that can help build more robust and adaptive emerging market systems. Furthermore, the success of cross-border arbitrage strategies suggests that emerging markets can respond effectively to global crises by establishing co-operative relationships with other markets. Policymakers should encourage and facilitate international co-operation to promote the closer integration of emerging markets into the global financial system. This is essential for facilitating cross-border capital flow and promoting global integration. However, our study has certain limitations that warrant acknowledgment. Given that this study is predicated on the construction of cross-border trading strategies across different markets, it would be advantageous to augment the portfolio by incorporating more markets and to broaden the study's scope to encompass multiple sectors, such as tourism, transportation, and telecommunications, in line with the research conducted by Blajer-Gołębiewska, Honecker and Nowak [56], Hu, Lang [57], Marzuki, Majid and Rosman [58]. Additionally, the optimization of trading models and algorithms to enhance their suitability for cross-market trading emerges as a critical area for future research endeavors.

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Data availability statement

The data will be made available on request.

CRediT authorship contribution statement

Wang Jialu: Writing – original draft, Software, Data curation. **Lingdi Zhao:** Supervision, Investigation, Conceptualization. **Hao Li:** Writing – review & editing. **Xiuqi Guo:** Visualization, Investigation.

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.

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References

[1] B.N. Iyke, M.M.J.D. Maheepala, Conventional monetary policy, COVID-19, and stock markets in emerging economies, Pac. Basin Finance J. 76 (2022).
[2] M. Insaidoo, et al., COVID-19 pandemic and stock market performance: a comparative study of emerging economies, Heliyon 9 (5) (2023) e16054.
[3] M.A. Harjoto, et al., How do equity markets react to COVID-19? Evidence from emerging and developed countries, J. Econ. Bus. 115 (2021) 105966.
[4] B.G. Buchanan, P.C. English, R. Gordon, Emerging market benefits, investability and the rule of law, Emerg. Mark. Rev. 12 (1) (2011) 47–60.
[5] S.F. Razmi, S.M.J. Razmi, The role of stock markets in the US, Europe, and China on oil prices before and after the COVID-19 announcement, Resour. Pol. 81 (2023).
[6] S. Boubaker, et al., COVID-19 and finance scholarship: a systematic and bibliometric analysis, Int. Rev. Financ. Anal. 85 (2023) 102458.
[7] Q. Jiang, Z. Xu, G. Ye, M. Pahlow, M. Hu, S. Qu, A systematic scoping review of environmental and socio-economic effects of COVID-19 on the global ocean-human system, Science of the total Envir 849 (2022) 157925.
[8] S.R. Baker, N. Bloom, S.J. Davis, The unprecedented stock market reaction to COVID-19, The Review of Asset Pricing Studies 10 (4) (2020) 742–758.
[9] S.R. Baker, N. Bloom, S.J. Davis, Covid-induced Economic Uncertainty, National Bureau of Economic Research, 2020.
[10] A. Zaremba, et al., Infected markets: novel coronavirus, government interventions, and stock return volatility around the globe, Finance Res. Lett. 35 (2020) 101597.
[11] D. Zhang, M. Hu, Q. Ji, Financial markets under the global pandemic of COVID-19, Finance Res. Lett. 36 (2020) 101528.
[12] B.N. Ashraf, Stock markets' reaction to COVID-19: cases or fatalities? Res. Int. Bus. Finance 54 (2020) 101249.
[13] B.N. Ashraf, Stock markets' reaction to Covid-19: moderating role of national culture, Finance Res. Lett. 41 (2021) 101857.
[14] M. Davidovic, From pandemic to financial contagion: high-frequency risk metrics and Bayesian volatility analysis, Finance Res. Lett. 42 (2021) 101913.
[15] U. Kayani, et al., Riding the waves: a study of retrun spillovers and inter-sector linkages in US equity markets during the COVID-19 pandemic, Heliyon (2024) 10 (4).
[16] S. Baek, S.K. Mohanty, M. Glambosky, COVID-19 and stock market volatility: an industry level analysis, Finance Res. Lett. 37 (2020) 101748.
[17] A.S. Baig, et al., Deaths, panic, lockdowns and US equity markets: the case of COVID-19 pandemic, Finance Res. Lett. 38 (2021) 101701.
[18] M. Mazur, M. Dang, M. Vega, COVID-19 and the march 2020 stock market crash. Evidence from S&P1500, Finance Res. Lett. 38 (2021) 101690.

[19] A.M. Al-Awadhi, et al., Death and contagious infectious diseases: impact of the COVID-19 virus on stock market returns, Journal of behavioral and experimental finance 27 (2020) 100326.
[20] R. Ichev, M. Marinč, Stock prices and geographic proximity of information: evidence from the Ebola outbreak, Int. Rev. Financ. Anal. 56 (2018) 153–166.
[21] J.W. Goodell, T.L.D. Huynh, Did Congress trade ahead? Considering the reaction of US industries to COVID-19, Finance Res. Lett. 36 (2020) 101578.
[22] A.A. Salisu, L.O. Akanni, X.V. Vo, Volatility spillovers and hedging effectiveness between health and tourism stocks: empirical evidence from the US, Int. Rev. Econ. Finance 74 (2021) 150–159.
[23] N.S. Al-Nassar, I. Yousaf, B. Makram, Spillovers between positively and negatively affected service sectors from the COVID-19 health crisis: implications for portfolio management, Pac. Basin Finance J. 79 (2023) 102009.
[24] A. Shleifer, R.W. Vishny, The limits of arbitrage, J. Finance 52 (1) (1997) 35–55.
[25] J.P. Broussard, M. Vaihekoski, Profitability of pairs trading strategy in an illiquid market with multiple share classes, J. Int. Financ. Mark. Inst. Money 22 (5) (2012) 1188–1201.
[26] M.C. Chiu, H.Y. Wong, Robust dynamic pairs trading with cointegration, Oper. Res. Lett. 46 (2) (2018) 225–232.
[27] N. Huck, Pairs trading and outranking: the multi-step-ahead forecasting case, Eur. J. Oper. Res. 207 (3) (2010) 1702–1716.
[28] S.M. Sarmento, N. Horta, Enhancing a pairs trading strategy with the application of machine learning, Expert Syst. Appl. 158 (2020).
[29] J.-W. Yang, et al., Pairs trading: the performance of a stochastic spread model with regime switching-evidence from the S&P 500, Int. Rev. Econ. Finance 43 (2016) 139–150.
[30] E. Gatev, W.N. Goetzmann, K.G. Rouwenhorst, Pairs trading: performance of a relative-value arbitrage rule, Rev. Financ. Stud. 19 (3) (2006) 797–827.
[31] B. Do, R. Faff, Are pairs trading profits robust to trading costs? J. Financ. Res. 35 (2) (2012) 261–287.
[32] B. Do, R. Faff, Does simple pairs trading still work? Financ. Anal. J. 66 (4) (2018) 83–95.
[33] G. Vidyamurthy, Pairs Trading: Quantitative Methods and Analysis, vol. 217, John Wiley & Sons, 2004.
[34] A.N. Burgess, Using Cointegration to Hedge and Trade International Equities, Applied quantitative methods for trading and investment, 2003, pp. 41–69.
[35] C.L. Dunis, G. Shannon, Emerging markets of South-East and Central Asia: do they still offer a diversification benefit? J. Asset Manag. 6 (3) (2005) 168–190.
[36] A. Galenko, E. Popova, I. Popova, Trading in the presence of cointegration, J. Altern. Investments 15 (1) (2012) 85.
[37] M. Hain, J. Hess, M. Uhrig-Homburg, Relative value arbitrage in European commodity markets, Energy Econ. 69 (2018) 140–154.
[38] K. Balladares, et al., Statistical arbitrage in emerging markets: a global test of efficiency, Mathematics 9 (2) (2021).
[39] J.P. Ramos-Requena, et al., A cooperative dynamic approach to pairs trading, Complexity 2021 (2021) 1–8.
[40] J.P. Ramos-Requena, J.E. Trinidad-Segovia, M.Á. Sánchez-Granero, An alternative approach to measure Co-movement between two time series, Mathematics 8 (2) (2020).
[41] J.P. Ramos-Requena, J.E. Trinidad-Segovia, M.Á. Sánchez-Granero, Some notes on the formation of a pair in pairs trading, Mathematics 8 (3) (2020).
[42] J. Cohen, Statistical power analysis, Curr. Dir. Psychol. Sci. 1 (3) (1992) 98–101.
[43] R.F. Engle, C.W. Granger, Co-integration and error correction: representation, estimation, and testing, Econometrica: J. Econom. Soc. (1987) 251–276.
[44] S. Johansen, Statistical analysis of cointegration vectors, J. Econ. Dynam. Control 12 (2–3) (1988) 231–254.
[45] C. Alexander, Optimal hedging using cointegration, Philos. Trans. R. Soc. London, Ser. A: Math. Phys. Eng. Sci. 357 (1758) (1999) 2039–2058.
[46] Y.-W. Ti, et al., Improving cointegration-based pairs trading strategy with asymptotic analyses and convergence rate filters, Comput. Econ. (2024) 1–29.
[47] D.A. Dickey, W.A. Fuller, Distribution of the estimators for autoregressive time series with a unit root, J. Am. Stat. Assoc. 74 (366a) (1979) 427–431.
[48] P.C. Phillips, P. Perron, Testing for a unit root in time series regression, Biometrika 75 (2) (1988) 335–346.
[49] M.S. Perlin, Evaluation of pairs-trading strategy at the Brazilian financial market, J. Deriv. Hedge Funds 15 (2) (2009) 122–136.
[50] P. Andrade, F. Ferroni, Delphic and odyssean monetary policy shocks: evidence from the euro area, J. Monetary Econ. 117 (2021) 816–832.
[51] Y. Jiang, M. Yu, S. Hashmi, The financial crisis and Co-movement of global stock markets—a case of six major economies, Sustainability 9 (2) (2017).
[52] D. Bowen, M.C. Hutchinson, N. O'Sullivan, High frequency equity pairs trading: transaction costs, speed of execution and patterns in returns, SSRN (2019).
[53] P. Jorion, Asset allocation with hedged and unhedged foreign stocks and bonds, J. Portfolio Manag. 15 (4) (1989) 49.
[54] O. Al Farooque, et al., Stock liquidity during COVID-19 crisis: a cross-country analysis of developed and emerging economies, and economic policy uncertainty, Emerg. Mark. Rev. 55 (2023) 101025.
[55] J.P. Ramos-Requena, J. Trinidad-Segovia, M. Sánchez-Granero, Introducing Hurst exponent in pair trading, Phys. Stat. Mech. Appl. 488 (2017) 39–45.
[56] A. Blajer-Gołębiewska, L. Honecker, S. Nowak, Investor sentiment response to COVID-19 outbreak-related news: a sectoral analysis of US firms, N. Am. J. Econ. Finance (2024) 102121.
[57] Y. Hu, et al., The impact of COVID-19 on the volatility connectedness of the Chinese tourism sector, Res. Int. Bus. Finance 68 (2024) 102192.
[58] M.M. Marzuki, W.Z.N.A. Majid, R. Rosman, Corporate social responsibility and Islamic social finance impact on banking sustainability post-COVID-19 pandemic, Heliyon (2023) 9 (10).