Computational Economics (2023) 62:1781–1799
https://doi.org/10.1007/s10614-022-10319-6

Profitability of Ichimoku-Based Trading Rule in Vietnam Stock Market in the Context of the COVID-19 Outbreak

Ha Che-Ngoc[1] · Nga Do-Thi[2] · Thao Nguyen-Trang[3,4]

Accepted: 30 August 2022 / Published online: 13 October 2022

Abstract
Ichimoku Kinkohyo or Ichimoku Cloud Chart is one of the most popular technical indicators used by traders all over the world. However, its profitability is heavily influenced by the market environment, to which it is applied. Furthermore, the COVID-19 outbreak may have an impact on the market environment as well as the performance of all technical indicators. This study is the first to look into the profitability of Ichimoku-based trading rules in the Vietnamese stock market in the context of the COVID-19 outbreak. More particularly, the COVID-19 outbreak has a positive influence on the performance of this strategy when considering the entire market as well as a variety of industries including real estate industry, food and beverage industry, resource industry, and automotive and electronic components industry. Compared to the pre-pandemic period, the return on investment obtained per each transaction using the Ichimoku-based strategy increased by roughly $8-9\%$ in the pandemic period. Compared to the Buy-and-hold method, the Ichimoku-based strategy could slightly increase Accumulated return while posing a lower risk. The findings indicate that the Ichimoku-based strategy is applicable to the Vietnam stock market, regardless of the adverse effects of the pandemic on the industries.

Keywords Vietnamese stock market · Ichimoku cloud · COVID-19 · Return on Investment · Non-parametric statistics

1 Introduction

In financial markets, investors frequently employ fundamental and technical analysis. While fundamental analysis focuses on examining financial statements to determine the optimal portfolio, technical analysis focuses on examining the historical data to determine the rules and optimal investing methods. Compared to the fundamental analysis, the technical analysis can help traders to take profit in a shorter period,

Extended author information available on the last page of the article

thereby reducing the risk of market uncertainty. There is a broad range of technical analysis methods, including indicator analysis (Roscoe & Howorth, 2009; Vasiliou et al., 2006), agent-based analysis (Alfarano et al., 2005), statistical analysis (Vo-Van et al., 2021; Vu et al., 2019; Yang et al., 2021), and soft computing techniques (Deng et al., 2015; Maciel & Ballini, 2021; Syriopoulos et al., 2021; Wiesinger et al., 2013). Despite the variety of technical analysis methods, most of them aim to find out appropriate buy/sell signals to open a transaction.

Among technical indicators, the Ichimoku Kinkohyo or Ichimoku cloud chart (Sanjin, 1969) is a very simple diagram that offers a reasonable understanding of market movements. Understanding the characteristics of the Ichimoku cloud chart can assist investors in developing short-term and medium-term investing plans. During the past two decades, several studies have examined the impact of Ichimoku-based strategies on various market situations. Deng et al. (2020) investigated the profitability of Ichimoku-based trading rules. They indicated that some Ichimoku-based trading strategies could prove profitable when trading stock indices, but not when trading currencies. The authors also encouraged improving the performance of Ichimoku-based strategies by applying some additional technical indicators. In Shawn et al. (2015), the authors studied four basic Ichimoku-based strategies on the Japanese and US stock markets. The results showed that the strategies could work well in both markets. In Gurrib et al. (2020), the authors studied the performance of Ichimoku Cloud in the leading US Energy Stocks market. The results showed the rationality of the method when buying/selling during strong bull/bearish periods. Almeida (2020) investigated the effectiveness of technical indicators including Ichimoku, Moving Average Convergence/Divergence (MACD), and Relative Strength Index (RSI) in investing in technology companies. The authors concluded that the Ichimoku-based strategy could offer higher returns and lower risks than other methods. The authors of Yee et al. (2021) investigated the effectiveness of the Ichimoku Could technical analysis on the Malaysian stock market. They claimed that the combined model of Japanese Candlestick and Ichimoku could achieve highly accurate entry points but only moderately accurate exit points. More in-depth reviews of the Ichimoku chart can be found at Elliott (2007); Patel (2010). *In summary, the effectiveness of the Ichimoku-based strategies has been investigated in different market environments in literature, however, no study has been conducted to investigate the performance of the Ichimoku-based strategies in Vietnam market so far (i).*

In the last two years, the COVID-19 pandemic has strongly affected almost all aspects, including financial markets, of countries all over the world. Numerous studies have been conducted to investigate the impact of the pandemic on financial markets and various investment strategies. The research in Danylchuk et al. (2020) demonstrated that cryptocurrencies were affected by the pandemic by calculating the Hurst coefficient and wavelet entropy. The authors claimed, however, that this effect would be negligible and that the cryptocurrency market would likely recover in the future. The research in Nandini and Samal (2020) investigated the impact of COVID-19 on the profitability of technical indicators including Simple Moving Average, Exponential moving average, Moving average convergence divergence, and Bollinger Band in the Indian stock market. They concluded that using the

combination of indicators would be likely to provide higher performance than using any individual indicator, under the cloud of the pandemic. Lee et al. (2020) examined the returns of six moving average (MA) rules for the Malaysian stock market. The MA (2.5) and MA(2,10) were found to be the most effective during the COVID-19 pandemic. Ramelli and Wagner (2020) focused on the impact of Coronavirus disease on the US market, specifically on Russell 3000 index companies. The authors identified negative consequences and warned that the health crisis would exacerbate the economic crisis. Many efforts have been conducted to investigate the impact of the pandemic on various financial markets, as can be referred in (Alam et al., 2020; Anh & Gan, 2020; Baker et al., 2020; Bogdan et al., 2021; Rebucci et al., 2020; Ryandono et al., 2021; Valle-Cruz et al., 2021). *In summary, although a number of studies have been conducted to investigate the impact of the COVID-19 outbreak on various investment strategies, none of them has investigated the impact of the pandemic on the profitability of Ichimoku chart-based strategies (ii).*

In order to fill the aforementioned researched gaps, this paper pioneers an investigation of the profitability of the Ichimoku-based strategy, when applied to the Vietnam stock market, in the context of the COVID-19 pandemic. Particularly, the return on investment (ROI), the accumulated return (AR), the Sharpe ratio (SR), and the Jensen alpha (JA) obtained from the strategy during the pre-pandemic and the pandemic periods are collected and analyzed. To the best of our knowledge, the profitability of the Ichimoku-based strategy in the Vietnam stock market has not been conducted by any scholar so far. Similarly, this is also the first study to examine the pandemic's influence on the profitability of the Ichimoku-based method. Table 1 summarizes the distinction between this paper and certain existing studies in the field of financial economics and other related areas.

The rest of this paper is organized as follows. Section 2 presents the background of the Ichimoku chart and the corresponding strategies. The data used and the methodology are presented in Sect. 3. The result and discussion are presented in Sect. 4. Section 5 is the conclusion.

2 Background

2.1 Ichimoku Chart

The Ichimoku chart is constructed by the five lines consisting of Tenkan ($T(t)$), Kijun ($K(t)$), Span A ($A(t)$), Span B ($B(t)$) and Chikou ($C(t)$). These five lines can be regarded as a useful set of indicators for determining open and exit signals. Let $x_o(t), x_c(t), x_{\min}(t), x_{\max}(t)$ represent the open, close, lowest, and highest prices at the time point t. The following part describes these five lines' properties and the method for calculating them.

– Tenkan: Tenkan, which displays short-term price movement, is widely regarded as the least reliable indicator in the Ichimoku system. A change in its direction, on the other hand, can aid investors in determining an early indication of a bend. Tenkan is determined by averaging the lowest and highest prices over the previous nine days.

Table 1 The distinction between this paper and certain existing studies

Research	Ichimoku	Vietnam stocks	COVID-19
Anh and Gan (2020)	No	Yes	Yes
Bogdan et al. (2021)	No	No	Yes
Danylchuk et al. (2020)	No	No	Yes
Deng et al. (2020)	Yes	No	No
Gurrib et al. (2020)	Yes	No	No
Lee et al. (2020)	No	No	Yes
Nandini and Samal (2020)	No	No	Yes
Ryandono et al. (2021)	No	No	Yes
Valle-Cruz et al. (2021)	No	No	Yes
Yee et al. (2021)	Yes	No	No
This paper	Yes	Yes	Yes

$$T(t) = \frac{\max x_{\max}(t-i) + \min x_{\min}(t-i)}{2}, i = 0, \ldots, 8. \tag{1}$$

– Kijun: Kijun is determined by averaging the lowest and highest prices over the previous 26 days (see Formula 2). Kijun can inherit Tenkan's properties, but it is more stable and reliable because it is based on a longer time frame.

$$K(t) = \frac{\max x_{\max}(t-i) + \min x_{\min}(t-i)}{2}, i = 0, \ldots, 25. \tag{2}$$

– Span A: Span A is determined by averaging Tenkan and Kiniu, then shifting it to 26 days forward. Mathematically, Span A is calculated as follows.

$$A(t) = \frac{T(t-25) + K(t-25)}{2}. \tag{3}$$

– Span B: Span B is determined by averaging the highest and lowest prices over the previous 52 days and then shifting it forward 26 days. Span B represents the long-term price equilibrium, which assists investors in developing a comprehensive view of the market and determining future investment strategies. Span B is calculated mathematically as follows.

$$B(t) = \frac{\max x_{\max}(t-i) + \min x_{\min}(t-i)}{2}, i = 25, \ldots, 76. \tag{4}$$

The region formed by Span A and Span B is called "Kumo" or "Cloud". Cloud is the most essential component of the Ichimoku chart as it can assist investors in getting a comprehensive view of the market trend and its relationship with the current price movement.

– Chikou: Chikou represents the current closing price shifting back to the previous 26 days. This clever shifting is essential, arguably because it allows investors to

observe price and trend in the present and the past at the same time. Then efficient comparison and prediction can be made. Mathematically, Chikou is calculated as follows.

$$C(t) = x_c(t + 25) \tag{5}$$

2.2 Ichimoku Chart Based Trading Strategy

Based on the five components of the Ichimoku system, researchers and investors have proposed various strategies, such as strategies based on the intersection of the Tenkan and Kijun lines, and strategies based on the intersection of the Chikou line and the Cloud. However, since the Tenkan line is often unreliable, in this paper we would not examine strategies that rely on Tenkan and Kijun crossover. In the remaining strategies, we also do not investigate the effectiveness of conservative strategies because they take a very long time for entry and exit signals. Furthermore, strategies for opening a short position would not be investigated because short selling is not permitted on the Vietnamese stock exchange. Therefore, a method, known as Aggressive Long-Only Strategy, is used as a proxy for Ichimoku chart-based trading strategies. This strategy is summarized as follows (Fig. 1).

Aggressive Long-Only Strategy

- *Open a long position when the Chikou line crosses the top of the Cloud from below.*
- *Close a long position when the Chikou line crosses the top of the Cloud from above.*

The components of the Ichimoku system and the Ichimoku-based trading strategy are depicted in the figure below.

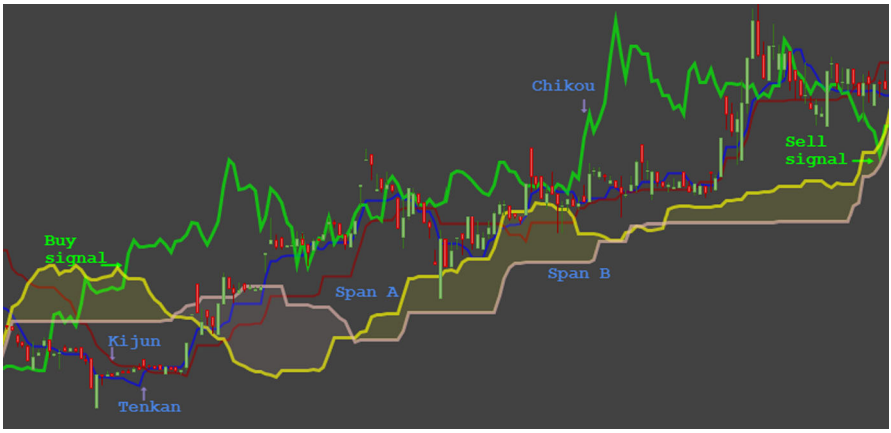


Fig. 1 An illustration of the components of Ichimoku system and the Ichimoku chart based trading strategy

For opening a long position, the above strategy is based on the meaning of the Cloud and the Chikou line. The Cloud or Kumo is formed by the two Span A and Span B lines in which Span A stands for the short-medium terms average and Span B stands for the long terms average. When the Chikou crosses the Cloud from below, the current price gets over the short terms, medium terms, and long terms averages of the past prices. Normally, when the current price is higher than the average past price, some investors tend to sell the stock, however, in this case, Ichimoku-based investors buy the stock and expect to catch a strong uptrend. With this point of view, these investors accept to lose a number of times with small amounts before taking a huge profit. Hence, the corresponding profitability is usually not a normal distribution. In the same manner, when the Chikou line crosses the Cloud from above, the current price is lower than the short, medium, and long terms averages of the past prices. This is an early warning sign of a bend. Therefore, in this case, investors would close the order and profit.

2.3 Comparative Ratios

In order to evaluate the performance of trading strategies, several measures have been developed in literature. Some widely used measures including the Return on investment (ROI), the accumulated return (AR), the Sharpe ratio (SR), and the Jensen alpha (JA) are presented as follows.

- Return on investment

$$ROI_i = \frac{P(t_2) - P(t_1)}{P(t_1)}, \tag{6}$$

  where ROI_i is the return on investment of transaction i, $P(t_1)$ and $P(t_2)$ are respectively the stock prices at the beginning and the end of the transaction.
- Accumulated return

$$AR(t) = \frac{P(t) - P(0)}{P(0)}, \tag{7}$$

  where $AR(t)$ denotes the accumulated return of at the time point t, $P(t)$ and $P(0)$ denotes the portfolio values at time point t and the beginning of the trading period, respectively.
- Sharpe ratio

$$SR = \frac{\bar{R} - R_f}{\sigma_R}, \tag{8}$$

  where $\bar{R}$ and σ_R are respectively the average and the standard deviation of return over time, R_f denotes the risk-free rate.
- Jensen alpha

$$JA = \bar{R} - R_f - \beta\big(R_m - R_f\big), \tag{9}$$

where $\bar{R}$ and R_m are respectively the expected return on an investment and the expected return on the market, R_f denotes the risk-free rate.

In this paper, R_f is set as 0.03, based on the Vietnam Government Bond. More details of these comparative ratios could be found in (Aldridge, 2013; Deng et al., 2020; Jensen, 1968; Sharpe, 1966, 1994).

2.4 Statistical Test and Simulation

2.4.1 Mann-Whitney U Test

The Mann-Whitney U test is a non-parametric test used to determine whether the difference between two independent populations' medians is equal to zero (El Fadl et al., 2015; Kelter, 2021; Legnazzi, 2018; Mann & Whitney, 1947). Let $x_1 = \{x_{11}, x_{12}, \ldots, x_{1m}\}$ and $x_2 = \{x_{21}, x_{22}, \ldots, x_{2n}\}$ be the samples drawn from two independent populations. Also, let the null and alternative hypotheses be: H_0-"the difference between the two medians is equal to 0" and H_1-"the difference between the two medians is not equal to 0". The Mann-Whitney U test can be conducted through the three following steps.

1. Rank all observations in ascending order, i.e, the smallest value is ranked first.
2. Calculate the test statistic U as follows:

$$U = \min\left\{\left(mn + \frac{m(m+1)}{2} - Rk_1\right), \left(mn + \frac{n(n+1)}{2} - Rk_2\right)\right\}, \quad (10)$$

where m is the sample size for Sample 1; Rk_1 is the sum of the ranks in Sample 1; n is the sample size for Sample 2; and Rk_2 is the sums of the ranks in Sample 2.

3. If $U \leq U_{m,n,\alpha}$, we reject H_0, and vice versa, where α represents the significance level; and $U_{m,n,\alpha}$ represents the critical value that may be derived using the Mann-Whitney table and statistical software.

2.4.2 Bootstrap Sampling

Bootstrap sampling (Berkowitz et al., 2021; Cinaroglu, 2021; Efron, 1992; Ledoit & Wolf, 2008; Sewell, 2017) is a common technique for assessing the robustness of a statistic of interest, denoted as ξ. Given an n-observation sample, $x = \{x_1, x_2, \ldots, x_n\}$, the Bootstrap sampling technique is summarized as follows.

1. Select n elements at random from x, with replacement.
2. Calculate the statistic of interest, ξ, based on the obtained sample.
3. Repeat the two above steps N times to obtain a bootstrap distribution of ξ, then derive the required information, such as the confidence interval for ξ.

2.4.3 Metropolis-Hastings Algorithm

Metropolis-Hastings Algorithm (MHA) (Glen, 2014; Hastings, 1970; Hoff, 2009; Metropolis et al., 1953) is also a frequently used technique for approximating the posterior distribution of ξ. Let $x = \{x_1, x_2, \ldots, x_n\}$ be a sample of n observations and $p(\xi)$ be the prior probability density function of ξ. The following summarizes the technique for performing the MHA.

1. Initialize a starting point $\xi(0)$.
2. For $t = 1, 2, \ldots, N$, draw a candidate ξ^* from a proposal distribution $q(\xi^*|\xi(t-1))$, where q is typically a symmetric function.
3. For $t = 1, 2, \ldots, N$, set:

$$\xi(t) := \begin{cases} \xi^* & \text{with probability } \min\{r(\xi(t-1), \xi^*), 1\} \\ \xi(t-1) & \text{otherwise} \end{cases}, \tag{11}$$

where

$$r(\xi(t-1), \xi^*) = \frac{p(\xi^*)p(x|\xi^*)q(\xi(t-1)|\xi^*)}{p(\xi(t-1))p(x|\xi(t-1))q(\xi^*|\xi(t-1))}. \tag{12}$$

4. Based on the generated data, calculate the necessary information, such as the confidence interval for ξ.

3 Data and Methodology

We collected the daily stock prices of 100 companies on Ho Chi Minh Stock Exchange (HOSE) using the systematic sampling method. The investment period is from 01/03/2019 to 28/02/2021. Based on the daily number of positive COVID-19 cases in Vietnam (https://ncov.vncdc.gov.vn/), the investment period is divided into two periods: the pre-pandemic period (from 01/03/2019 to 29/02/2020) and the pandemic period (from 01/03/2020 to 28/02/2021). Similarly, there were three waves of Coronavirus in Vietnam during the investment periods; thus, the second period is divided into three sub-periods: Sub-period 2.1 (from 01/03/2020 to 31/05/2020), Sub-period 2.2 (from 01/06/2020 to 31/10/2020) and Sub-period 2.3 (from 01/11/2020 to 28/02/2021).

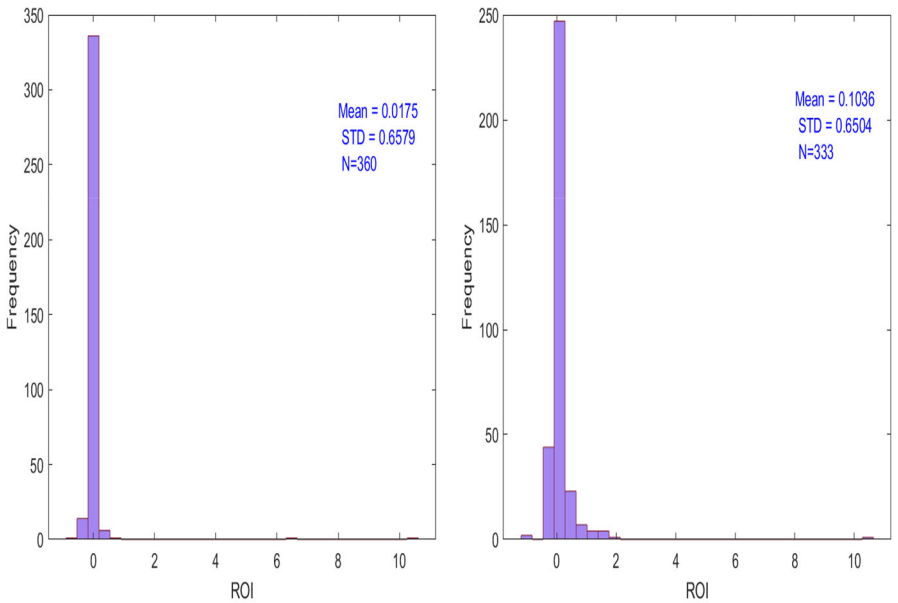
The profitability of the Ichimoku-based strategy is evaluated based on the Return on investment(ROI). And afterward, the differences between the ROI obtained in periods/sub-periods are identified based on the statistical test. For the Ichimoku-based strategy, the obtained profitability usually does not follow a Normal or a Student's t-distribution; thus, the non-parametric Mann-Whitney U test rather than the independent samples t test is used in this paper. The above process is also conducted to verify the differences between the ROI acquired in the two periods when considering specific business industries. In addition to the ROI, other typical measures, such as the AR, SR, and JA, are also utilized to evaluate the performance of the Ichimoku-based strategy. Of available works evaluating the effectiveness of

trading strategies, most used the Buy-and-hold method as a benchmark (Coe & Laosethakul, 2021; Hui & Chan, 2019; Zhang & Khushi, 2020). Therefore, we include the AR acquired using the Ichimoku-based strategy and the Buy-and-hold method, for further comparison. Finally, Bootstrap sampling and the Metropolis-Hastings algorithm are employed to determine the robustness of the obtained results.

4 Empirical Results

4.1 The Profitability of the Ichimoku Based Strategy in the Entire Market

The histograms of the ROI obtained on the two periods are represented in Fig. 2. It can be seen that the obtained mode values are less than 0 for both cases, which indicates that investors would lose a large number of times, as stated in Sect. 2.2. However, in both pre-pandemic and pandemic periods, there are a number of abnormal positive ROIs which are equal to around 6 to 12 times the mean values. This indicates the efficiency of the Ichimoku-based strategy when it can capture strong bullish signals. Generally, as shown in Table 2, the average values of ROIs are positive for both cases, but the average value of ROI obtained in the pandemic period is much higher than that in the pre-pandemic period.



(a) Period 1 **(b)** Period 2

Fig. 2 Histogram of obtained ROI

The Mann-Whitney U test is used to determine whether the ROI obtained during the pandemic period is higher than that obtained during the pre-pandemic period. As shown in Table 2, the obtained p-value is equal to 2.8×10^{-5}, implying that the pandemic has a positive effect on the profitability obtained from the Ichimoku-based strategy, at a significance level of 5%. Because the pandemic had a negative impact on overall production and business activities, particularly real estate investing, which is one of the most common businesses in Vietnam, investors were said to have no choice but to invest in the stock market. The more money that flows in, the higher the price, and vice versa. This leads to the fact that most companies' stock prices have increased during the pandemic period, even though the economy has been depressed, negatively affecting the companies' financial status.

For further analysis, the pandemic period is separated into three sub-periods that correspond to the three waves of infection during the inquiry period. Table 3 provides the obtained pairwise p-values when performing the Mann-Whitney U tests over the four periods consisting of Period 1 (pre-pandemic), Sub-period 2.1 (pandemic), Sub-period 2.2 (pandemic), and Sub-period 2.3 (pandemic).

According to Table 3, at a 5% significance level, there is no difference in the ROI produced from an Ichimoku-based approach during Period 1 and Subperiod 2.1 (p-value is equal to 0.986). In Sub-period 2.1, when the Covid-19 pandemic appearance was announced in Vietnam for the first time, investors were mainly cautious. According to our knowledge, many investors suddenly withdrew from the market due to the declining economic situation. In this sub-period, there were not many new investments, the stock market fluctuated very slightly. Therefore, the Ichimoku-based strategy, which aims to profit from strong market trends, was not very effective.

For Sub-periods 2.2 and 2.3, the Mann-Whitney U test shows the differences between the ROI obtained in these sub-periods and Period 1, with 5% and 1% significance levels, respectively. This demonstrates that the profit earned from the Ichimoku-based strategy tended to improve gradually in the later sub-periods. During sub-periods 2.2 and 2.3, stock prices were increased, regardless of the business situation. As previously stated, the prolonged pandemic situation halted production and business operations at the time. As a result, only a few investment avenues remained viable, including the stock market. The stock market had a strong uptrend due to the continuous inflow of money, which was consistent with the benefits of the Ichimoku-based strategy.

In summary, during the investigated periods, the profit obtained using the Ichimoku-based strategy was better and better over time. Ichimoku-based strategy

Table 2 Statistics of obtained ROI on the two periods

Periods	N	Mean	Std. Deviation	Std. Error Mean	p-value
1	360	0.0175	0.6579	0.0347	–
2	333	0.1036	0.6504	0.0356	–
U test	–	–	–	–	0.000028

Table 3 *p*-values of Mann-Whitney Tests when comparing ROI obtained from sub-periods

p-values	Period 1	Sub-period 2.1	Sub-period 2.2	Sub-period 2.3
Period 1	–	0.986	0.001	0.000
Sub-period 2.1	0.986	–	0.038	0.000
Sub-period 2.2	0.001	0.038	–	0.067
Sub-period 2.3	0.000	0	0.067	–

correctly identified the buy signals so that investors could capture the strong uptrend of the stock market, under the influences of the prolonged pandemic situation.

4.2 The Profitability of the Ichimoku Based Strategy in Industries

The Mann-Whitney U test with a statistical significance value of 0.05 is used to further analyze the effects of the pandemic on the profitability of the Ichimoku-based strategy by industry. The null hypothesis H_0 is constructed as follows: "there is no difference in the profitability of the Ichimoku-based strategy obtained in the two periods, by industry x", where x is the industry under consideration. Table 4 displays the test results.

The test results in Table 4 show that the difference in the profitability of the Ichimoku-based strategy obtained in the two periods is significant for four industries: Real estate, Food and beverages, Resources, and Automotive and electronic

Table 4 *p*-values of Mann-Whitney Tests when comparing ROI obtained in the two periods by industry

ID	Sectors	Period 1	Period 2	*p*-values
1	Real estate	−0.023	0.109	0.042
2	Bank	−0.063	0.049	0.508
3	Covenient service	−0.05	0.038	0.165
4	Retail services	0.363	−0.063	0.856
5	Medical	−0.012	−0.009	0.719
6	Personal and household goods	−0.047	0.012	0.178
7	Food and beverages	−0.055	0.119	0.003
8	Industrial goods and services	−0.019	0.071	0.122
9	Building services	0.134	0.103	0.318
10	Resources	−0.026	0.553	0.039
11	Chemistry	−0.025	0.05	0.426
12	Technology	0.006	−0.018	0.806
13	Financial services	−0.012	0.274	0.289
14	Insurance	−0.018	0.001	0.564
15	Travel and leisure	0.002	0.104	1.000
16	Automotive and electronic components	−0.053	0.085	0.042

components. The findings show that industry was an important factor in investment. Some of the best industries for investors were those that could grow or could be not adversely affected by the pandemic. For example, it can be seen from Table 4 that the Food and beverages industry has a significant difference in the profitability of Ichimoku-based strategy between the two periods. This industry provides people with essential and nutritional foods which saw a significant increase in demand during the pandemic. This enabled food and beverages to become the most reliable and profitable industry. In contrast, the differences in profitability of Ichimoku-based strategy between the two periods are not significant for some other industries, e.g, Travel and leisure. The Travel and leisure industry was hit the hardest by the COVID-19 pandemic. This industry saw a significant decrease in demand during the pandemic because people were not permitted to travel for an extended time. As a result, the financial status of tourist agencies, as well as the corresponding stock prices, were impacted. However, in general, as shown in Table 4, most industries achieve either a positive or a very small negative value in ROI. This demonstrates that the Ichimoku-based strategy can be considered a suitable method with low risk, no matter if there were adverse influences on the industry during the pandemic.

In order to provide more informative results, other typical measures, such as the accumulated returns (AR), Sharpe ratio (SR), and Jensen alpha (JA) are also utilized to evaluate the performance of the Ichimoku-based strategy. The AR, SR, and JA are provided in Table 5, where the smaller values are in bold. As illustrated in Table 5, Period 2 saw a significant increase in terms of AR and SR. Meanwhile, trading with the Ichimoku-based strategy in this period still achieved a competitive JA for the majority of industries.

Particularly, regarding the AR and SR, their values sharply increased for the entire market as well as the specific industries. For the entire market, the AR rose from -7% in Period 1 to 19% in Period 2 while the SR also rose from -2.02 to 1.19 in the same periods. For the majority of industries, such as the Real estate, Food and beverages, Building services, Resources, and Financial services, utilizing Ichimoku-based strategy in Period 2 a experienced considerable increase in AR and SR. Meanwhile, in the pandemic period, the Ichimoku-based strategy still attained slightly better performance for the rest of the sectors.

Regarding JA, while Period 2 saw a rise in JA for several sectors, this figure slightly declined for the total market. The reason is that the Ichimoku-based strategy outperformed the market in Period 1, but not in Period 2. During Period 1, stock prices did not increase and even depreciated. The Ichimoku-based approach with its exit signal might prevent severe losses, despite the fact that it would incur somewhat negative profit. As a result, the Ichimoku-based strategy outperformed the market in this period, resulting in a positive JA. In contrast, even though the entry signal of the Ichimoku-based strategy could capture strongly upward trends in Period 2 and generated positive AR and SR, it took time to verify the signal, i.e., was slower than the market. Consequently, the Ichimoku-based strategy could not beat the market, resulting in a negative JA throughout this time.

For further analyses, we compare the AR received using the Ichimoku-based strategy and the Buy-and-hold method which is a well-known benchmark often used in trading strategy evaluation. As shown in Fig. 3, the Ichimoku-based strategy

Table 5 The cumulative returns, Sharpe Ratio, and Jensen alpha of the Ichimoku-based trading rule

Industries	Accumulated return		Sharpe Ratio		Jensen alpha	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Entire market	−0.07	**0.19**	−2.02	**1.19**	**0.11**	−0.14
Real estate	−0.16	**0.32**	−0.82	**1.21**	−0.15	**0.14**
Bank	0.00	**0.01**	−0.24	**−0.08**	**0.02**	−0.12
Covenient service	−0.15	**0.05**	−1.81	**0.12**	**−0.11**	−0.21
Medical	−0.09	**0.01**	−1.07	**−0.24**	**−0.11**	−0.19
Household goods	−0.16	**0.04**	−2.17	**0.07**	−0.16	**−0.15**
Food and beverages	−0.09	**0.48**	−3.43	**0.69**	−0.08	**0.36**
Industrial services	−0.13	**0.15**	−0.32	**0.63**	−0.17	**−0.02**
Building services	0.12	**0.35**	0.78	**2.22**	0.15	**0.20**
Resources	−0.19	**0.54**	−2.12	**1.58**	−0.18	**0.42**
Chemistry	−0.16	**0.16**	−1.44	**0.64**	−0.16	**0.03**
Technology	−0.12	**0.08**	−2.38	**0.22**	−0.13	**−0.04**
Financial services	−0.03	**0.41**	−0.62	**1.49**	−0.04	**0.28**
Insurance	**−0.05**	−0.08	−2.07	**−0.38**	**−0.05**	−0.26
Travel and leisure	−0.05	**0.16**	−1.69	**0.83**	−0.07	**−0.01**
Automotive industry	0.03	**0.19**	0.01	**0.49**	0.00	**0.10**

achieved slightly higher AR and significantly lower risk than that of the Buy-and-hold method. During Period 1, the Buy-and-Hold strategy generated significantly negative returns as the stock price gradually declined. Regarding the Ichimoku-based strategy, it prompted investors to exit the market when the Chikou line crossed the cloud, thereby preventing substantial losses. The Ichimoku-based strategy, therefore, outperformed the Buy-and-Hold method in terms of AR and risk, throughout this time period. At the beginning of Period 2, when the COVID-19 pandemic was announced in Vietnam for the first time, the market suddenly fell. As a result, the AR

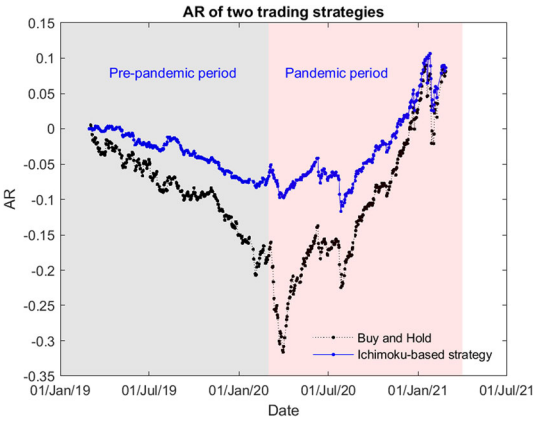


Fig. 3 AR of the two methods

of the Buy-and-hold method reached the bottom at about -32%. Meanwhile, the AR of the Ichimoku-based strategy was approximately -10% at that time, which was 3 times better than that of the Buy-and-hold option. The outlined result again demonstrates the superiority of the Ichimoku-based strategy over the Buy-and-hold strategy. Nevertheless, the sharp increase in the market afterward let the Buy-and-hold strategy become the most suitable option for the rest of the pandemic period. Compared to the Buy-and-hold method, the Ichimoku-based strategy had a slower increase in terms of AR as this method needed time to verify an entry signal. Therefore, during the pandemic period, the Ichimoku-based strategy was unable to beat the market even though this strategy significantly outperformed itself in the previous time. Throughout the two periods, the final AR values of the Ichimoku-based strategy and the Buy-and-hold strategy were about 8.14% and 8.65%, respectively. The preceding results demonstrate that the Ichimoku-based strategy could slightly increase AR while posing a lower risk, in comparison to the Buy-and-hold method.

4.3 Robustness Check

The Mann-Whitney U test utilized in Sects. 4.1 and 4.2 requires certain assumptions, such as the similarity of the sample distributions in terms of dispersion and shape. Therefore, robustness checks need to be conducted to clarify whether the obtained results are well-established regardless of various kinds of data conditions and beliefs. For this purpose, this subsection utilizes the Bootstrap sampling and the Metropolis-Hasting sampling to verify the robustness of the Mann-Whitney U test.

Let $X_1 = \{x_{11}, x_{12}, \ldots, x_{1m}\}$ be the data set of ROI in Period 1 and let $X_2 = \{x_{21}, x_{22}, \ldots, x_{2n}\}$ be the data set of ROI in Period 2. We first combine them to form a new data set containing ROI differences between the two periods, e.g., $X_2 - X_1 = \left\{x_{2j} - x_{1i}\right\}_{i=\overline{1,m}, j=\overline{1,n}}$. The Bootstrap sampling describe in Sect. 2 is then utilized to obtain the 95% confidence interval for $\mu(x_2 - x_1)$ or μ_d.

Figure 4 depicts the distribution of μ_d, based on 10000 Bootstrap samples. It can be seen from Fig. 4 that the mean of difference is likely to have a normal distribution. The 95% confidence interval for μ_d is approximately $[0.0809, 0.0913]$, which shows that the ROI obtained per each transaction using the Ichimoku-based strategy increases by roughly $8 - 9\%$ in the pandemic period. This also verifies the robustness of the Mann-Whitney U test conducted in the previous subsections.

In addition to the Bootstrap sampling, the Metropolis-Hastings algorithm (MHA) is utilized for the purpose of robustness check. Conducting the MHA requires a given distribution of the difference $X_2 - X_1$, and a prior distribution of μ_d. In this paper, we set $(X_2 - X_1) \sim N(\mu_d, \sigma_d)$ and $\mu_d \sim N(\theta, \tau)$, where σ_d is given by the sample variance of $(X_2 - X_1)$, $\theta > 0$ indicates a belief of positive difference and vice versa.

Figure 5 illustrates the trace plot of 10000 samples generated by MHA, with $\theta = 0$ and $\tau = 0.05$. During the simulation process, the samples with higher likelihoods are repetitively collected in certain regions, e.g. region R1. Meanwhile, the samples with smaller likelihoods are still accepted in a few regions, e.g., region R2. The above mechanisms ensure an adequate approximation of the posterior expectation, along

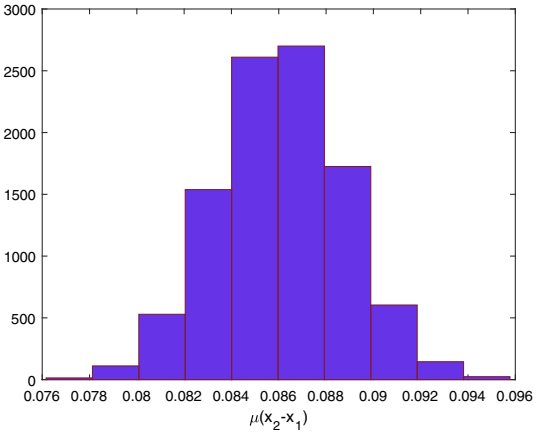


Fig. 4 The distribution of $\mu(x_2 - x_1)$ using Bootstrap sampling

with an acceptable level of the posterior dispersion. The 95% confidence interval for μ_d in this case is approximately $[0.0809, 0.0915]$. Finally, we investigate the posterior 95% confidence interval, under various cases of prior probability. As shown in Fig. 6, all confidence intervals are positive, even though the prior distribution has a negative mean and large variance. Again, the results outlined confirm the robustness of the Mann-Whitney U test conducted earlier.

5 Conclusion

In this paper, the profitability of the Ichimoku-based strategy on the Vietnamese stock market, under the impact of the COVID-19 pandemic is investigated for the first time. The findings indicate that the profitability of Ichimoku-based strategy in the pandemic period was significantly better than that in the pre-pandemic period, in terms of ROI, AR, and SR. Additionally, we examine the profitability of Ichimoku-based strategy in a variety of industries and obtain similar results. The robustness check reiterates that the ROI obtained per each transaction using the Ichimoku-based strategy increased by roughly $8 - 9\%$ in the pandemic period. Compared to the Buy-

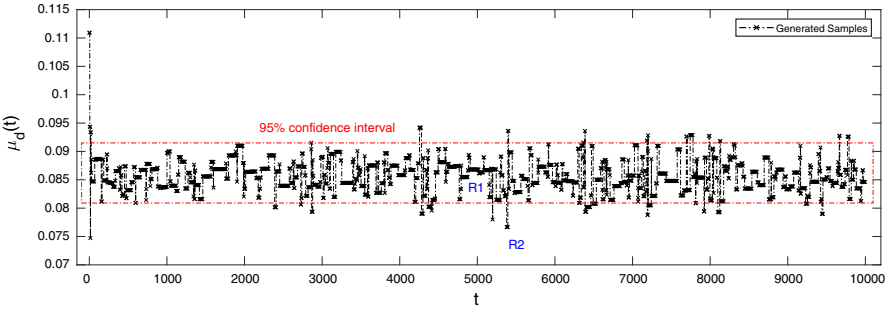


Fig. 5 The traceplot of 10000 generated samples

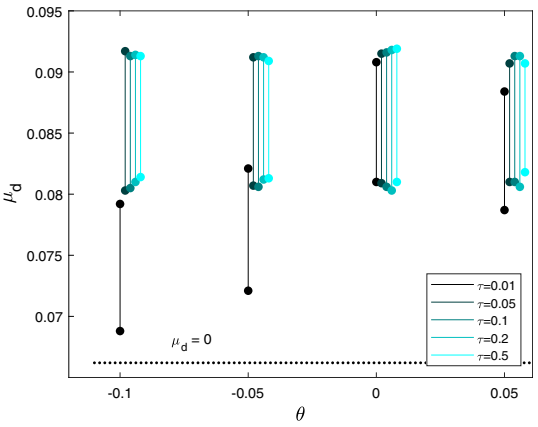


Fig. 6 The effects of prior distribution on the posterior 95% confidence interval

and-hold method, the Ichimoku-based strategy could slightly increase AR while posing a lower risk. Generally, this strategy could be considered a suitable method for applying to the Vietnam stock market, regardless of the adverse effects of the pandemic on the industries. The findings in this paper could be considered useful references for researchers and investors working in financial economics and other related fields. Nevertheless, this paper only considers the conventional Ichimoku-based strategy, without any modification. Therefore, the strategy has less potential to beat the market in the pandemic period. Also, certain state-of-the-art statistical methods, e.g., the Bayesian Mann-Whitney test, have not been applied in this paper. These drawbacks are also interesting research directions that need to be conducted in the future.

Funding Thao Nguyen-Trang receives the research support from Ton Duc Thang University.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

Alam, M. N., Alam, M. S., & Chavali, K. (2020). Stock market response during covid-19 lockdown period in india: An event study. *The Journal of Asian Finance, Economics, and Business, 7*(7), 131–137.

Aldridge, I. (2013). High-frequency trading: a practical guide to algorithmic strategies and trading systems, vol. 604. John Wiley & Sons

Alfarano, S., Lux, T., & Wagner, F. (2005). Estimation of agent-based models: The case of an asymmetric herding model. *Computational Economics, 26*(1), 19–49.

Almeida, L. A. G. (2020). Technical indicators for rational investing in the technology companies: The evidence of FAANG stocks. *Journal Pengurusan, 59,* 75–87.

Anh, D.L.T., Gan, C. (2020). The impact of the covid-19 lockdown on stock market performance: evidence from vietnam. Journal of Economic Studies

Baker, S. R., Bloom, N., Davis, S. J., Kost, K., Sammon, M., & Viratyosin, T. (2020). The unprecedented stock market reaction to covid-19. *The review of asset pricing studies, 10*(4), 742–758.

Berkowitz, S. T., Sternberg, P., Jr., & Patel, S. (2021). Cost analysis of routine vitrectomy surgery. *Ophthalmology Retina, 5*(6), 496–502.

Bogdan, D., DIMA, Ş.M., Roxana, I. (2021). Remarks on the behaviour of financial market efficiency during the covid-19 pandemic. The case of vix. Finance Research Letters p. 101967

Cinaroglu, S. (2021). Oncology services efficiency in the age of pandemic: A jackknife and bootstrap sensitivity analysis for robustness check of dea scores. *Journal of Cancer Policy, 27,* 100262.

Coe, T. S., & Laosethakul, K. (2021). Applying technical trading rules to beat long-term investing: Evidence from Asian markets. *Asia-Pacific Financial Markets, 28*(4), 587–611.

Danylchuk, H., Kibalnyk, L., Kovtun, O., Kiv, A., Pursky, O., Berezhna, G. (2020). Modelling of cryptocurrency market using fractal and entropy analysis in Covid-19. In M3E2-MLPEED, pp. 352–371

Deng, S., Huang, X., Wang, J., Qin, Z., Fu, Z., Wang, A., & Yang, T. (2020). A decision support system for trading in apple futures market using predictions fusion. *IEEE Access, 9,* 1271–1285.

Deng, S., Yoshiyama, K., Mitsubuchi, T., & Sakurai, A. (2015). Hybrid method of multiple kernel learning and genetic algorithm for forecasting short-term foreign exchange rates. *Computational Economics, 45*(1), 49–89.

Deng, S., Yu, H., Wei, C., Yang, T., Tatsuro, S. (2020). The profitability of ichimoku kinkohyo based trading rules in stock markets and fx markets. International Journal of Finance & Economics

Efron, B. (1992). Bootstrap methods: another look at the jackknife. In: Breakthroughs in statistics, pp. 569–593. Springer

El Fadl, M.A., Abbey, B., Choi, K.S. (2015). Effect of it trading platform on financial risk-taking and portfolio performance. In 2015 48th Hawaii International Conference on System Sciences, pp. 3298–3306. IEEE

Elliott, N. (2007). Ichimoku Charts: An Introduction to Ichimoku Kinko Clouds. Harriman House Limited

Glen, S. (2014). Excel Statistics: Step by Step. CreateSpace Independent Publishing Platform

Gurrib, I., Kamalov, F., & Elshareif, E. E. (2020). Can the leading us energy stock prices be predicted using Ichimoku clouds? *International Journal of Energy Economics & Policy, 11*(1), 41–51.

Hastings, W. K. (1970). Monte Carlo sampling methods using markov chains and their applications. *Biometrika, 57*(1), 97–109.

Hoff, P.D. (2009). A first course in Bayesian statistical methods, vol. 580. Springer (2009)

Hui, E. C., & Chan, K. K. K. (2019). Alternative trading strategies to beat "buy-and-hold." *Physical A: Statistical Mechanics and its Applications, 534,* 120800.

Jensen, M. C. (1968). The performance of mutual funds in the period 1945–1964. *The Journal of Finance, 23*(2), 389–416.

Kelter, R. (2021). Bayesian and frequentist testing for differences between two groups with parametric and nonparametric two-sample tests. *Wiley Interdisciplinary Reviews: Computational Statistics, 13*(6), e1523.

Ledoit, O., & Wolf, M. (2008). Robust performance hypothesis testing with the sharpe ratio. *Journal of Empirical Finance, 15*(5), 850–859.

Lee, K., Binti zaidi, N. S., & Wen, C. C. (2020). Technical analysis and Malaysian banking sector during Covid-19 pandemic. *UNIMAS Review of Accounting and Finance, 4*(1), 41–46.

Legnazzi, C. (2018). Derivative securities in risk management and asset pricing. Ph.D. thesis, Università della Svizzera italiana

Maciel, L., & Ballini, R. (2021). Functional fuzzy rule-based modeling for interval-valued data: An empirical application for exchange rates forecasting. *Computational Economics, 57*(2), 743–771.

Mann, H.B., Whitney, D.R. (1947). On a test of whether one of two random variables is stochastically larger than the other. The annals of mathematical statistics, pp. 50–60

Metropolis, N., Rosenbluth, A. W., Rosenbluth, M. N., Teller, A. H., & Teller, E. (1953). Equation of state calculations by fast computing machines. *The Journal of Chemical Physics, 21*(6), 1087–1092.

Nandini, G., Samal, R. (2020). Technical analysis of selected industry leaders of indian stock market under the cloud of Covid-19. Gedrag & Organisate Review, **33**(3)

Patel, M. (2010). Trading with Ichimoku clouds: The essential guide to Ichimoku Kinko Hyo technical analysis. John Wiley & Sons)

Ramelli, S., & Wagner, A. F. (2020). Feverish stock price reactions to Covid-19. *The Review of Corporate Finance Studies, 9*(3), 622–655.

Rebucci, A., Hartley, J. S., & Jiménez, D. (2020). *An event study of Covid-19 central bank quantitative easing in advanced and emerging economies*. Cambridge: National Bureau of Economic Research.

Roscoe, P., & Howorth, C. (2009). Identification through technical analysis: A study of charting and uk non-professional investors. *Accounting, Organizations and Society, 34*(2), 206–221.

Ryandono, M. N. H., Muafi, M., & Guritno, A. (2021). Sharia stock reaction against Covid-19 pandemic: Evidence from Indonesian capital markets. *The Journal of Asian Finance, Economics, and Business, 8*(2), 697–710.

Sanjin, I. (1969). *Ichimoku Kinkohyo*. Tokyo, Japan: Keizaihendousouken Co., Ltd.

Sewell, M.V. (2017). Application of machine learning to financial time series analysis. Ph.D. thesis, UCL (University College London)

Sharpe, W. F. (1966). Mutual fund performance. *The Journal of Business, 39*(1), 119–138.

Sharpe, W. F. (1994). The sharpe ratio. *The Journal of Portfolio Management, 21*(1), 49–58.

Shawn, K., Yanyali, S., Savidge, J. (2015). Do ichimoku cloud charts work and do they work better in japan. International Federation of Technical Analysts Journal

Syriopoulos, T., Tsatsaronis, M., & Karamanos, I. (2021). Support vector machine algorithms: An application to ship price forecasting. *Computational Economics, 57*(1), 55–87.

Valle-Cruz, D., Fernandez-Cortez, V., López-Chau, A., Sandoval-Almazán, R. (2021). Does twitter affect stock market decisions? financial sentiment analysis during pandemics: A comparative study of the h1n1 and the Covid-19 periods. Cognitive computation pp. 1–16)

Vasiliou, D., Eriotis, N., & Papathanasiou, S. (2006). How rewarding is technical analysis? evidence from Athens stock exchange. *Operational Research, 6*(2), 85–102.

Vo-Van, T., Che-Ngoc, H., Le-Dai, N., Nguyen-Trang, T. (2021). A new strategy for short-term stock investment using bayesian approach. Computational Economics pp. 1–25

Vu, H., Van, T. V., Nguyen-Minh, N., & Nguyen-Trang, T. (2019). A technique to predict short-term stock trend using bayesian classifier. *Asian Journal of Economics and Banking, 3*(2), 70–83.

Wiesinger, J., Sornette, D., & Satinover, J. (2013). Reverse engineering financial markets with majority and minority games using genetic algorithms. *Computational Economics, 41*(4), 475–492.

Yang, Y., Du, R., Tang, H., Zheng, Y.: Sslpnet (2021). A financial econometric prediction model for small-sample long panel data. In 2021 The 9th International Conference on Information Technology: IoT and Smart City, pp. 174–180

Yee, L.L., Mei, H.L., Isharuddin, L., et al. (2021). Ichimoku cloud and japanese candlestick prediction combination pattern approached: The case study of malaysia stock market. Multidisciplinary Applied Research and Innovation **2**(2)

Zhang, Z., Khushi, M. (2020). Ga-mssr: Genetic algorithm maximizing sharpe and sterling ratio method for robotrading. In: 2020 International Joint Conference on Neural Networks (IJCNN), pp. 1–8. IEEE

Authors and Affiliations

Ha Che-Ngoc[1] · Nga Do-Thi[2] · Thao Nguyen-Trang[3,4]

✉ Thao Nguyen-Trang
thao.nguyentrang@vlu.edu.vn

Ha Che-Ngoc
chengocha@tdtu.edu.vn

Nga Do-Thi
ngadodt.tt@gmail.com

[1] Faculty of Mathematics and Statistics, Ton Duc Thang University, Ho Chi Minh City, Vietnam

[2] School of Management, College of Business, University of Economics Ho Chi Minh City, Ho Chi Minh City, Vietnam

[3] Laboratory for Applied and Industrial Mathematics, Institute for Computational Science and Artificial Intelligence, Van Lang University, Ho Chi Minh City, Vietnam

[4] Faculty of Basic Sciences, Van Lang University, Ho Chi Minh City, Vietnam