Stock Market Efficiency and International Market Integration -- Empirical Analysis with the Chinese CSI 1000 Index

Panfei Zhang*

Skyline College, San Bruno, United States

*Corresponding author: panfeizhang@my.smccd.edu

Abstract. Based on daily stock returns from 2016 to 2023, the study digs into the return pattern of the Chinese A share stock index. The study first adopts the ARMA framework for the analysis of serial correlation of daily stock return. The univariate analysis shows the positive autocorrelation of stock return, which indicates the momentum feature of the stock market in the short run and rejects the efficient market hypothesis. Then the study extends the autoregression model to ARDL regression with information from American and Japanese stock markets to test for the information spillover effect. The multivariate analysis shows evidence of stock market integration, as the Chinese stock market responds to the condition of regional and global markets. Moreover, the subsample analysis shows an improvement in Chinese stock market efficiency with reduced serial correlation. Meanwhile, the responsiveness of the Chinese stock market to international markets has been lower with COVID-19 as well.

Keywords: Efficient market hypothesis, Stock market integration; Information spillover.

1. Introduction

Understanding the behavior of stock market returns is important for two reasons. Firstly, from the aspect of stock investors, the predictability of stock return indicates the chance to improve stock investment performance. Secondly, from the theoretical perspective, it is associated with assessing stock market efficiency and analyzing the fair value of company shares [1].

The study sets up to model the return of the Chinese CSI 1000 index from the aspect of stock return serial correlation and the information spillover between countries. In particular, the study adopts the ARMA framework to evaluate the existence of stock market momentum or reversal effect [2]. It adopts the ARDL framework to assess the integration of the Chinese stock market with international markets [3].

In detail, the study intends to answer three research questions: (1) Whether the Chinese stock market is efficient or serially correlated. (2) Whether the Chinese stock market is integrated with global and regional stock markets. (3) What is the impact of COVID-19 on the Chinese stock market and the information spillover between stock markets?

The rest of the study contains four sections with the content arranged as follows. Section 2 discusses the data and methodology of analysis. Section 3 discusses the benchmark research findings. Section 4 detects the structural break pre- and post-COVID-19 pandemic. Section 5 discusses the implications and concludes the analysis.

2. Data and Research Methodology

2.1. Data Source and Variables

The study obtains data from the Bloomberg database. Three series are selected for analysis: the CSI 1000 index, the S&P 500 index, and the NIKKEI 225 index, which are the representative stock market indexes of China, the US, and Japan respectively [4-6]. The data frequency is chosen to be daily to capture short-term stock market serial correlation and information contagion. The sampling period is from Jan. 2016 to Nov. 2023, which covers an adequate sample size for the comparison before and after the COVID-19 pandemic. The overall sample size is 2077 trading days.

The three series of market index prices are combined based on trading date. In particular, the American stock market price is lagged by one trading day to account for the issue of time zone. In addition, to account for missing data due to national holidays, the last observation is carried forward for imputation. The corresponding assumption is a zero daily return for days with a trading halt.

To reflect the performance of three stock markets, the adjusted close price is taken for analysis and the inter-day log return is calculated as:

$$logret_t = (logp_t - logp_{t-1}) * 100\% \tag{1}$$

2.2. Exploratory Analysis

Table 1. Summary statistics

VarName	Mean	SD	Min	Median	Max	Skewness	Kurtosis
retcsi1000	-0.021	1.451	-9.196	0.000	5.100	-1.046	8.381
retsp500	0.039	1.158	-12.765	0.028	8.968	-0.853	19.921
retnikkei225	0.029	1.202	-8.253	0.000	7.731	-0.177	8.307

The summary statistics are shown in Table 1 above. It indicates an unsatisfactory performance of the Chinese stock market during the sampling period, with an average daily loss of 0.021%. On the contrary, the S&P 500 generates a daily return of 0.039%, and Nikkei generates a daily return of 0.029%. Apart from the poor return performance, the Chinese stock market is found to be more volatile than the other two countries, with a standard deviation highest among the three. However, in terms of the spread of daily return, the S&P 500 is documented to have the highest risk with a wide range of return fluctuations. This is because the American stock market does not have restrictions to cap daily return change or forbid intraday transactions as in China [7].

Table 2. Correlation coefficient

	retcsi1000	retsp500	retnikkei225
retcsi1000	1		
retsp500	0.113	1	
retnikkei225	0.215	0.199	1

Then the correlation coefficients in Table 2 indicate preliminary evidence for the integration of the Chinese stock market with the other two countries. This is because a positive return association is detected. In particular, the integration of the Chinese stock market with Japan is found to be deeper with a larger correlation coefficient.

2.3. Research Methodology

2.3.1 Pre-estimation diagnostic test

To avoid the problem of spurious regression for time series analysis, the study first excludes the issue of non-stationarity with the ADF test of unit root [8, 9]. Three model forms are considered in the stationarity analysis (none, drift, and trend models) and the length of lag in the regression is determined with AIC statistics. The hypothesis of the ADF test is listed as:

$$H0: \rho = 0 \; Nonstationarity$$

$$H1: \rho < 0 \; Stationarity \tag{2}$$

When the null hypothesis is not rejected and the unit root is detected, the first difference is taken to ensure stationarity before model construction.

2.3.2 Single variable modeling

The study first conducts univariate analysis based on the ARIMA framework. The Box Jenkins [10] approach is adopted for model construction, which takes three steps. The first step employs ACF and PACF plots for a preliminary decision about the optimal lagged length for estimation. The cutting-off point of ACF indicates the proper MA order and the cutting-off point of PACF indicates the proper AR order. The second step conducts estimation with candidate models determined in the preliminary analysis. The third step conducts model selection based on the AIC and BIC statistics. In particular, information criteria balance model fitness and model complexity to avoid overfitting problems, for which the model with the least AIC and BIC statistics should be selected. The associated model is depicted as follows:

$$csi1000_t = \Sigma_{s=1}^{p} \beta_s csi1000_{t-s} + \Sigma_{s=1}^{q} \theta_s e_{t-s} + e_t \quad (3)$$

2.3.3 Multiple variable modeling

Apart from the univariate analysis, the study extends the analysis to multivariate modeling based on the ARDL framework to detect the existence of information spillover from foreign stock markets into China. In particular, the study intends to reveal whether the Chinese stock market is integrated with the global market (US) and regional market (Japan) respectively. The study considers three model forms containing only global integration, regional integration, and combining the two respectively. The associated regression models are depicted as follows:

$$csi1000_t = \Sigma_{s=1}^{p_1} \beta_s^1 csi1000_{t-s} + \Sigma_{s=0}^{p_2} \beta_s^2 SP500_{t-s} + e_t \quad (4)$$

$$csi1000_t = \Sigma_{s=1}^{p_1} \beta_s^1 csi1000_{t-s} + \Sigma_{s=0}^{p_3} \beta_s^3 NIKKEI225_{t-s} + e_t \quad (5)$$

$$csi1000_t = \Sigma_{s=1}^{p_1} \beta_s^1 csi1000_{t-s} + \Sigma_{s=0}^{p_2} \beta_s^2 SP500_{t-s} + \Sigma_{s=0}^{p_3} \beta_s^3 NIKKEI225_{t-s} + e_t \quad (6)$$

For simplicity, the study only considers models with symmetric lagged lengths for all return series and considers the maximum lagged length to be two. Model selection is again based on information criteria after regression.

3. Benchmark Analysis

3.1. Stationarity Check

ADF test leads to the rejection of the null hypothesis for all return series for the three stock markets. Stationarity is confirmed and the model is free from the concern of spurious regression (Table 3).

Table 3. ADF test results

Model	CSI1000	SP500	NIKKEI225
None	-23.76	-23.63	-22.22
Drift	-23.81	-23.74	-22.25
Trend	-23.83	-23.75	-22.25

3.2. Single Variable Analysis

3.2.1 Correlogram

The correlogram indicates no strong MA component of the series, while there is moderate autocorrelation up to the six-lagged term. In turn, ARIMA estimation with integration order being zero, MA order being zero, and AR order ranges from one to six should be conducted (Fig. 1).

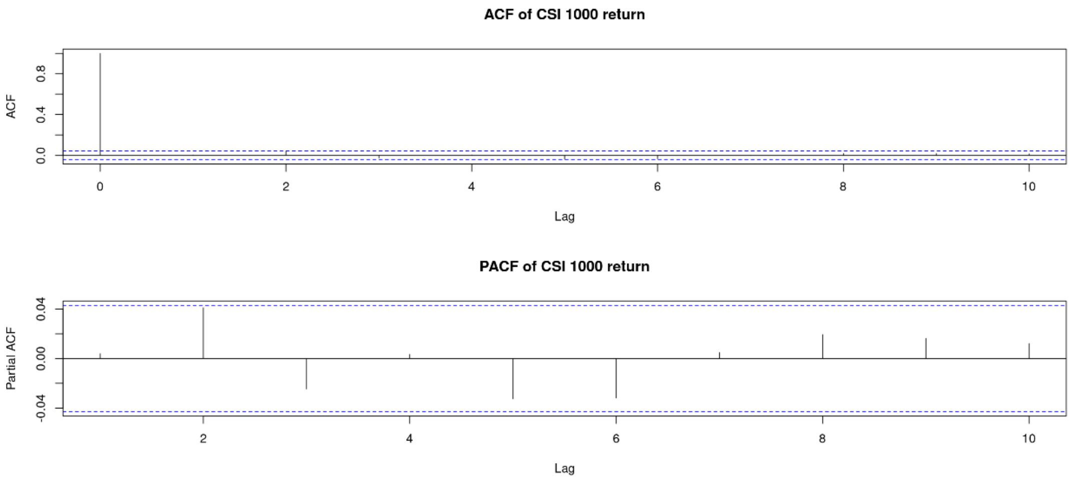

Fig. 1 Correlogram of CSI 1000 index return (Photo/Picture credit: Original).

3.2.2 ARIMA estimation

Table 4. ARIMA estimation of CSI 100 index return

	(1) retcsi1000	(2) retcsi1000	(3) retcsi1000	(4) retcsi1000	(5) retcsi1000	(6) retcsi1000
L.ar	0.0040	0.0037	0.0047	0.0048	0.0048	0.0037
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
L2.ar		0.041**	0.042**	0.041**	0.041**	0.041**
		(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
L3.ar			-0.025	-0.025	-0.025	-0.025
			(0.017)	(0.017)	(0.017)	(0.017)
L4.ar				0.0037	0.0042	0.0048
				(0.017)	(0.017)	(0.017)
L5.ar					-0.034	-0.034
					(0.018)	(0.018)
L6.ar						-0.032
						(0.018)
sigma						
_cons	1.45***	1.45***	1.45***	1.45***	1.45***	1.45***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
N	2076	2076	2076	2076	2076	2076
AIC	7441.6	7440.1	7440.8	7442.7	7442.4	7442.3
BIC	7458.5	7462.6	7469.0	7476.6	7481.8	7487.4

Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 reports the ARIMA estimation with different order lengths. The AIC statistics favor the AR (2) model while the BIC statistics favor the AR (1) model. The estimation indicates evidence against the efficient market hypothesis. In detail, a positive autocorrelation is documented with the Chinese stock market. Take the AR (2) estimation as an example (model selection is based on AIC and statistical significance of the AR terms), the second-order AR coefficient is 0.041 and statistically significant. It means that for a one percent rise in stock market return, the return on the day after the next day is expected to be higher by 0.041 percent. The effect of positive serial correlation is statistically significant at the level of 1%, indicating the predictability of the Chinese stock market.

This is in contrast with the efficient market hypothesis, which argues that historical information has no power to predict future returns in the asset market [11]. On the contrary, the finding is in line with the underreaction of the stock market, which suggests that stock market adjustment to news announcements is insufficient and there is a continuous market adjustment that drives a positive autocorrelation post-event announcement [12, 13].

3.3. Multiple Variable Analysis

Extending the ARIMA estimation to incorporate information from global and regional stock markets, Table 5 reports the ARDL estimation results. The first two columns conduct a bivariate analysis of Chinese stock market return with American stock market return, the next two columns are bivariate analyses of Chinese stock market return and Japanese stock market return, and the last two columns correspond to tri-variate ARDL estimation. The AIC statistics favor the tri-variate model with two lagged orders, while the BIC statistics favor the tri-variate model with one lagged order. Considering the statistical significance of the largest lagged term, the ARDL (1, 1, 1) model is selected for analysis.

The estimation indicates strong evidence for stock market integration. On the one hand, there is a regional market integration, as a one percent higher return in the Japanese stock market is associated with a 0.19 percent higher return in the Chinese stock market on the same trading day. The effect is statistically significant at the level of 1%. However, the information incorporation is quick and there is no lagged response from the Chinese stock market to the Japanese stock market. On the other hand, the Chinese stock market responds on both the same trading day and on the next trading day fluctuation of the American stock market. The instant response is by 0.12 and the permanent response is by 0.23. Both the two slope coefficients are statistically significant at the level of 1%.

Putting together, table 5 provides supportive evidence for the integration of the Chinese stock market with both a global market and regional market [14]. In particular, the intraday response is stronger for the regional market and the incorporation of information from the regional market is more quickly in comparison with the global market as well.

Table 5. ARDL estimation for stock market integration

	(1) retcsi1000	(2) retcsi1000	(3) retcsi1000	(4) retcsi1000	(5) retcsi1000	(6) retcsi1000
L.retcsi1000	-0.0093	-0.011	0.011	0.013	0.0075	0.0071
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
L2.retcsi1000		0.040		0.045^{*}		0.042
		(0.022)		(0.022)		(0.022)
retsp500	0.17^{***}	0.17^{***}			0.12^{***}	0.12^{***}
	(0.027)	(0.027)			(0.029)	(0.029)
L.retsp500	0.20^{***}	0.20^{***}			0.11^{***}	0.12^{***}
	(0.028)	(0.028)			(0.032)	(0.034)
L2.retsp500		0.026				0.030
		(0.028)				(0.032)
retnikkei225			0.26^{***}	0.26^{***}	0.19^{***}	0.19^{***}
			(0.026)	(0.026)	(0.030)	(0.031)
L.retnikkei225			-0.00097	0.00098	-0.026	-0.038
			(0.027)	(0.026)	(0.027)	(0.031)
L2.retnikkei225				-0.0021		-0.011
				(0.027)		(0.027)
_cons	-0.034	-0.036	-0.027	-0.028	-0.033	-0.035
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
N	2075	2074	2075	2074	2075	2074
AIC	7361.1	7353.7	7340.1	7332.8	7321.5	7315.4
BIC	7383.6	7387.5	7362.7	7366.6	7355.4	7366.1

Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4. Structural Break Analysis

To check for the effect of COVID-19 on the stock market, table 6 presents the subsample estimation for two periods separated by the pandemic. It indicates the changing behavior of the Chinese A share stock market in three aspects.

Firstly, the autocorrelation of stock return becomes statistically insignificant in the second subsample, which indicates the improvement of stock market efficiency.

Secondly, for global market integration, the concurrent and lagged response to the American stock market was reduced with COVID-19.

Thirdly, for regional market integration, the concurrent response to the Japanese stock market reduces with COVID-19, while no lagged response is detected for both two subsamples.

Table 6. Comparison of pre-and post-Covid-19 periods

	(1)	(2)	(3)	(4)
	Pre Covid-19		Post Covid-19	
	retcsi1000	retcsi1000	retcsi1000	retcsi1000
L.retcsi1000	-0.022	-0.015	0.038	0.039
	(0.029)	(0.031)	(0.027)	(0.032)
L2.retcsi1000	0.056**	0.074*	0.018	0.0016
	(0.019)	(0.031)	(0.022)	(0.031)
retsp500		0.15*		0.11***
		(0.060)		(0.032)
L.retsp500		0.21**		0.093*
		(0.069)		(0.038)
L2.retsp500		0.015		0.034
		(0.069)		(0.036)
retnikkei225		0.20***		0.17***
		(0.047)		(0.040)
L.retnikkei225		0.00017		-0.075
		(0.048)		(0.040)
L2.retnikkei225		-0.056		0.035
		(0.042)		(0.035)
_cons	-0.052	-0.069	0.012	-0.0013
	(0.054)	(0.046)	(0.050)	(0.042)
N	1065	1063	1011	1011
AIC	3929.4	3865.7	3502.1	3440.5
BIC	3949.3	3910.4	3521.7	3484.7

Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5. Conclusion

With ARMA and ARDL modeling, the study digs into the stock return performance of the Chinese A-share index. The ARMA analysis indicates the existence of serial correlation, which casts doubt on the efficient market hypothesis. Then the ARDL analysis indicates the existence of stock market integration. Especially, while the global market has a stronger permanent effect, the response to the regional market is more rapid. In addition, the heterogeneity of stock return patterns before and after the pandemic is detected with the subsample analysis.

Such a result indicates a potential room for arbitrage for stock investors by following a momentum trading strategy based on domestic, regional, and global market returns. However, the window for making a profit is narrow as the adjustment toward equilibrium is speedy. From the aspect of policymakers, the study indicates the importance of improving stock market efficiency with the reduction of market frictions (eg. short selling constraint).

As for future analysis, there are two aspects for further extension. For one thing, while the study focuses on modeling

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