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The Impact of North Korea's Nuclear Tests on Asian Stock Markets

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Abstract

This study investigates the impact of North Korea's nuclear tests on Asian stock markets. Two approaches are used separately in order to identify how stock market returns and volatilities change immediately after the nuclear tests. We find that the Chinese stock market tends to be more sensitive to unexpected shocks from North Korea's nuclear tests than other Asian stock markets. However, relatively, the Japanese stock market is little influenced by the nuclear tests though Japan is not only geographically close to North Korea but also politically vigilant to North Korea's nuclear threats. Also, we find that strengthened return correlations (linearity) do not necessarily increase stock return volatilities.

Keywords: *North Korea, Nuclear Test, Stock Market, Correlation, Volatility*

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1. Introduction

Since the Korean War ended in a military armistice in 1953, sporadic military threats of North Korea have threatened the security and economy of its southern counterpart, South Korea. In addition, military threats have usually been made as sudden or unexpected shocks without any advance warning or announcement. Particularly, from 2006 to 2017, North Korea conducted six provocative nuclear tests: the first test on October 9, 2006; the second test on May 15, 2009; the third test on February 12, 2013; the fourth test on January 6, 2016; the fifth test on September 9, 2016; and the sixth test on September 3, 2017, and these nuclear tests caused worldwide concern. Since then, North Korea has attempted to take advantage of denuclearization as a bargaining chip in order to negotiate economic sanctions imposed by the United States.

Some studies show how North Korea's nuclear tests affect the South Korean stock market (Choi & Park, 2010; Lim, 2012; Kollias et al., 2014; Kim & Roland, 2014; Huh & Pyun, 2018). However, since no studies examine the impact of North Korea's nuclear tests on Asian stock markets other than the South Korean stock market, the purpose of our study is to extend previous research on the financial impact of North Korea's nuclear tests by considering adjacent Asian countries. We pose two research questions. First, is there any significant change in return movements of Asian stock markets (other than the South Korean stock market) immediately after North Korea's nuclear tests? Second, are the volatilities of Asian stock markets affected by North Korea's nuclear tests in the same manner? Our study provides new insights into the literature by seeking to answer these questions.

With the South Korean stock market as a base stock market, we examine the impact of North Korea's nuclear tests on Asian stock markets: China, Indonesia; Malaysia; India; Thailand; Singapore, and Japan. In other words, we identify return and volatility movements of Asian stock markets relative to those of the South Korean stock market before and after each nuclear test. The reason why we use the indirect approach through the South Korean stock market as a base market is that not every Asian country may be directly affected by North Korea's nuclear tests. Based on our return analysis, we find that the Chinese stock market and the Thailand stock market appear to be more sensitive to North Korea's nuclear tests than the other Asian stock markets. In addition, the Chinese stock market has some reflective effect from the sixth nuclear test because its return correlation becomes significantly negative after the test. However, the Japanese stock market is relatively little impacted by the nuclear tests though it is geographically very close to North Korea. Also, we find that the volatilities of the Chinese stock market are relatively more influenced by the nuclear tests than those of the other Asian stock markets and strengthened return correlations (linearity) do not necessarily lead volatilities to increase.

The remainder of the paper is presented as follows. The following three sections provide the literature review, data, and models, respectively. Section 5 discusses empirical findings and Section 6 concludes.

2. Literature Review

While many studies analyze North Korea's military threats, they usually deal with issues from political interests or a security perspective (Mazarr, 1995; Hughes, 1996; Harrison, 2000; Howard, 2004; Dai & Hyun, 2009; Hughes, 2009; Moon & Lee, 2010; Kim & Lee, 2011; Jung & Park, 2014; Jung, 2016; Mastro, 2018; Nycz, 2018; Choi, 2019; Youn, 2019; DiFilippo, 2020; Husenicova, 2020; Kim, 2020). Although only a few studies investigate if North Korea's nuclear tests have an impact on financial markets, most of them focus on the South Korean stock market because the South Korean stock market is expected to be most significantly and immediately influenced by North Korea's nuclear tests.

Choi and Park (2010) examine the impact of the first nuclear test conducted by North Korea as well as several verbal threats through the press or media. They find that the South Korean stock market tends to be influenced by the nuclear test rather than verbal threats by identifying significant changes in trading volume and activities immediately after the nuclear test. Lim (2012) also identifies significant impacts of North Korea's first and second nuclear tests on the South Korean stock market and finds that more than 5 days are needed for the stock market recovery. Kollias et al. (2014) find that North Korea's second nuclear test has greater adverse effects on the South Korean stock market than the first test and the third test. Although Kim and Roland (2014) investigate several military threats of North Korea, including the first nuclear test, and do not find a significant impact on South Korean financial markets, they focus on other military threats rather than the nuclear test. Huh and Pyun (2018) examine North Korea's first, second, and third nuclear tests using Google search volume index (SVI). They show that the nuclear tests have a negative impact on the South Korean stock market, and the impact of the first nuclear test is most significant. Overall, it seems that North Korea's nuclear tests significantly influence the South Korean stock market.

3. Data

We collect daily stock market index data for Asian countries' stock markets from 2006 to 2017 in order to fully cover all six nuclear tests conducted by North Korea. All data are obtained from investing.com. With South Korea (KOSPI) as a base country, those Asian countries are China (SSE), Indonesia (IDX), Malaysia (FTSE BURSA KCLI), India (NIFTY), Thailand (SET), Singapore (STI), and Japan (NIKKEI). To examine return and volatility changes triggered by each nuclear test, we need to determine the pre-test period and the post-test period. Since the pre-test period should be neither too long nor too short and also, there is only a 9-month gap between the fourth nuclear test and the fifth nuclear test; we choose 90 days prior to each nuclear test date as the pre-test period in order to avoid any overlapped or after-test lingering effect even if it is minimal. Since Lim (2012) and Huh and Pyun (2018) show that significant after-test effects tend to last for several days at most, we define the (influential) post-test period in a similar way by dividing it into smaller sub-periods (post 5-, 10-, 15-, and 20-day) for the purpose of providing more comparable results such as strong and weak evidence. Table 1 summarizes descriptive statistics for eight Asian stock market indices.

Table 1. Descriptive Statistics

	S. Korea	Japan	China	Thailand	Indonesia	Singapore	India	Malaysia
Panel A: 1st Nuclear Test (October 9, 2006)								
M	0.0004	0.0005	0.0010	-0.0003	0.0002	0.0006	0.0006	0.0007
SD	0.0118	0.0134	0.0134	0.0114	0.0118	0.0117	0.0117	0.0118
SK	-0.2105	-0.2896	-1.3821	-0.5792	-0.2061	-0.2365	-0.2172	-0.2341
KU	1.1232	0.8742	4.4996	0.9076	1.1043	1.2686	1.2333	1.1118
JB	16.9558**	22.2498**	45.3293**	26.2173**	17.2499**	14.7647**	15.1706**	17.3459**
Panel B: 2nd Nuclear Test (May 15, 2009)								
M	0.0020	0.0008	0.0037	0.0024	0.0016	0.0016	0.0021	0.0012
SD	0.0203	0.0218	0.0182	0.0177	0.0201	0.0191	0.0200	0.0194
SK	-0.0629	0.0609	-0.3173	-0.0975	-0.0689	-0.2521	-0.1230	-0.1751
KU	0.6587	0.1712	0.9048	0.8853	0.8419	0.9245	0.8752	0.7932
JB	25.1968**	36.7441**	21.9667**	20.6715**	21.4333**	20.9090**	20.9701**	22.8834**
Panel C: 3rd Nuclear Test (February 12, 2013)								
M	0.0000	0.0024	0.0009	0.0020	0.0001	0.0000	0.0000	0.0000
SD	0.0066	0.0127	0.0121	0.0062	0.0068	0.0067	0.0066	0.0070
SK	0.1303	0.2352	0.3176	-0.1811	0.1118	0.1833	0.2375	-0.0369
KU	0.0516	-0.0771	1.7869	-0.0713	0.3830	0.1291	0.3148	0.3203
JB	40.1543**	44.4108**	8.5939*	43.8341**	31.6184**	38.3927**	34.0815**	32.9374**
Panel D: 4th Nuclear Test (January 6, 2016)								
M	-0.0003	-0.0015	-0.0034	-0.0006	-0.0003	-0.0002	-0.0003	-0.0003
SD	0.0105	0.0190	0.0266	0.0110	0.0103	0.0103	0.0102	0.0103
SK	0.0212	0.5050	-0.9378	-0.5577	0.0121	0.0105	0.0410	0.0553
KU	0.2126	2.0004	1.5858	2.7565	0.2309	0.2094	0.3470	0.2735
JB	35.6186**	9.2548**	25.2890**	5.9742	35.1465**	35.6950**	32.2910**	34.1285**
Panel E: 5th Nuclear Test (September 9, 2016)								
M	0.0002	-0.0003	0.0004	0.0000	0.0001	0.0001	0.0002	0.0001
SD	0.0073	0.0152	0.0099	0.0093	0.0067	0.0068	0.0072	0.0069
SK	-1.1592	-1.5481	-1.4952	-0.3486	-1.2639	-1.1262	-1.2175	-1.1703
KU	3.3071	7.1631	9.7336	2.1544	4.4224	3.9039	3.8030	3.8663
JB	25.0682**	123.3702**	248.8039**	5.5057	38.5601**	26.9979**	30.1288**	28.5471**
Panel F: 6th Nuclear Test (September 3, 2017)								
M	0.0010	0.0009	0.0004	0.0005	0.0011	0.0010	0.0010	0.0013
SD	0.0063	0.0063	0.0056	0.0036	0.0066	0.0061	0.0062	0.0064
SK	0.6883	0.4982	-0.0436	0.6795	-0.0690	-0.3583	-0.2132	-0.3461
KU	5.4336	0.8236	1.9596	5.0812	1.6305	2.4380	1.9555	2.3996
JB	35.8294**	26.2610**	4.9961	28.3181**	8.6838*	3.8011	5.8341	3.8484

Note: M = Mean, SD = Standard Deviation, SK = Skewness, KU = Kurtosis, and JB = Jarque-Bera. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

The statistics in Table 1 are calculated over the pre-and the post-test periods of each nuclear test. The Jarque-Bera test shows that most of the daily returns on those stock market indices are not normally distributed.

Next, Table 2 shows the date and time for each nuclear test in the South Korea standard time and return changes in the South Korean stock market. The BTDR (Before-Test Day Return), ATDR (After-Test Day Return), and AADR (Arithmetic Average Daily Return) represent daily index return during the previous day of the test, daily index return during the day or next day of the test (if the test day is a holiday), and arithmetic average daily index return for the pre-test period, respectively. All ATDRs are negative. This means that stock returns after all six nuclear tests immediately decrease or keep decreasing regardless of positive or negative BTDRs. Also, all ATDRs are negatively large relative to their AADRs.

Table 2. Return Changes in the South Korean Stock Market before and after Nuclear Tests

Nuclear Test	Date	Time	BTDR	ATDR	AADR
1st Test	October 9, 2006	10:30AM	-1.6301%	-1.7632%	0.0183%
2nd Test	May 25, 2009	10:00AM	-1.2671%	-0.2032%	0.2465%
3rd Test	February 12, 2013	12:00PM	0.9854%	-0.2623%	-0.0320%
4th Test	January 6, 2016	10:30AM	0.6115%	-0.2645%	-0.0256%
5th Test	September 9, 2016	9:30AM	0.0897%	-1.2610%	0.0263%
6th Test	September 3, 2017	12:30PM	-0.2330%	-1.1964%	0.1033%

Note: BTDR, ATDR, and AADR are as follows.
BTDR (Before-Test Day Return): Daily index return during the previous day of the nuclear test. ATDR (After-Test Day Return): Daily index return during the day or the next day of the nuclear test (if the test day is a holiday). AADR (Arithmetic Average Daily Return): Arithmetic average daily return for the pre-test period (90 days prior to the nuclear test date)

4. Models

We investigate the impact of North Korea's nuclear tests on Asian stock markets in terms of stock return and volatility changes. As Huang et al. (2018) mention, there may be some different ways to get this done. However, since we attempt to measure the impact of North Korea's nuclear tests by identifying return and volatility movements of Asian stock markets relative to those of the South Korean stock market, we adopt the Fisher's Z transformation employed by Huang et al. (2018) for stock return movements and the AR-GARCH model for stock volatility movements in order to reflect their time-varying feature.

First, in order to identify the impact of North Korea's nuclear tests on stock market returns, we calculate return correlations between the South Korean stock market and the other Asian stock markets for the pre-and the post-test periods and then test their significance to see if there is any significant change from the pre-test period to the post-test period. Given that the South Korean stock market is substantially influenced by North Korea's nuclear tests, if the return correlation between a country's stock market and the South Korean stock market significantly increases or decreases during the post-test period, we confirm that the country's stock market is affected by North Korea's nuclear tests. The following Fisher's Z transformation is used with a variance of 1/(N-3) where N is a sample size.

$$\mathrm{Z} = \frac{\ln\left(1+\rho_{post}\right)\left(1-\rho_{pre}\right) - \ln\left(1-\rho_{post}\right)\left(1+\rho_{pre}\right)}{2\sqrt{\dfrac{(N_{post}-3)+(N_{pre}-3)}{\left(N_{post}-3\right)\left(N_{pre}-3\right)}}} \quad (1)$$

where ρ_{pre}, ρ_{post}, N_{pre}, and N_{post} are correlations and sample sizes of the pre-test period and the post-test period, respectively. We examine if there exists a significant correlation change from the pre-test period to the post-test period.

Second, we examine how the volatilities of the Asian markets change relative to those of the South Korean stock market during the post-test period. We employ the following AR-GARCH model with an exogenous dummy variable. Ferenstein and Gasowski (2004) describe the AR-GARCH model in more detail.

$$R_{it} = \alpha + \sum_{j=1}^{p} \alpha_{ij} L^j R_{it} + \varepsilon_{it} \quad (2)$$

$$\varepsilon_{it} | \Pi_{it-1} \sim N(0, \sigma_{it}^2)$$

where R_{it} is the country i's return at time t, p is the number of lags, Lj is a lag operator, and $\Pi_{it-1}$is an information set at time t-1.

$$\sigma_{it}^2 = \beta_0 + \sum_{j=1}^{p} \beta_j L^j \varepsilon_{it}^2 + \sum_{j=1}^{q} \theta_j L^j \sigma_{it}^2 + \gamma_{NT} D_{NT} \varepsilon_{kor,t}^2 \quad (3)$$

where $\varepsilon_{kor,t}^2$ are squared errors of the South Korean stock market returns and D_{NT} is the exogenous dummy that equals 1 if t is after the nuclear test date and 0 otherwise. Equation (2) and (3) constitute mean and variance equations as one single system. In Figure 1, the volatilities of the Asian stock markets show distinct fluctuations over time, which means that they significantly vary over time. Thus, the variance equation should incorporate time-varying volatilities.

We adopt the GARCH (1, 1) that is most widely used to model time-varying volatilities. In Equation (3), if γ_{NT} is significantly positive (negative), there exists positive (negative) volatility changes from the South Korean stock market to the other Asian stock markets.

Because the post 5- to 10-day periods and the post 15- to 20-day periods represent strong evidence and weak evidence, respectively, and our previous return results are consistent with this grouping, in order to see volatility changes, we divide the post-test period into only two sub-periods: post 10-day as strong evidence and post 20-day as weak evidence.

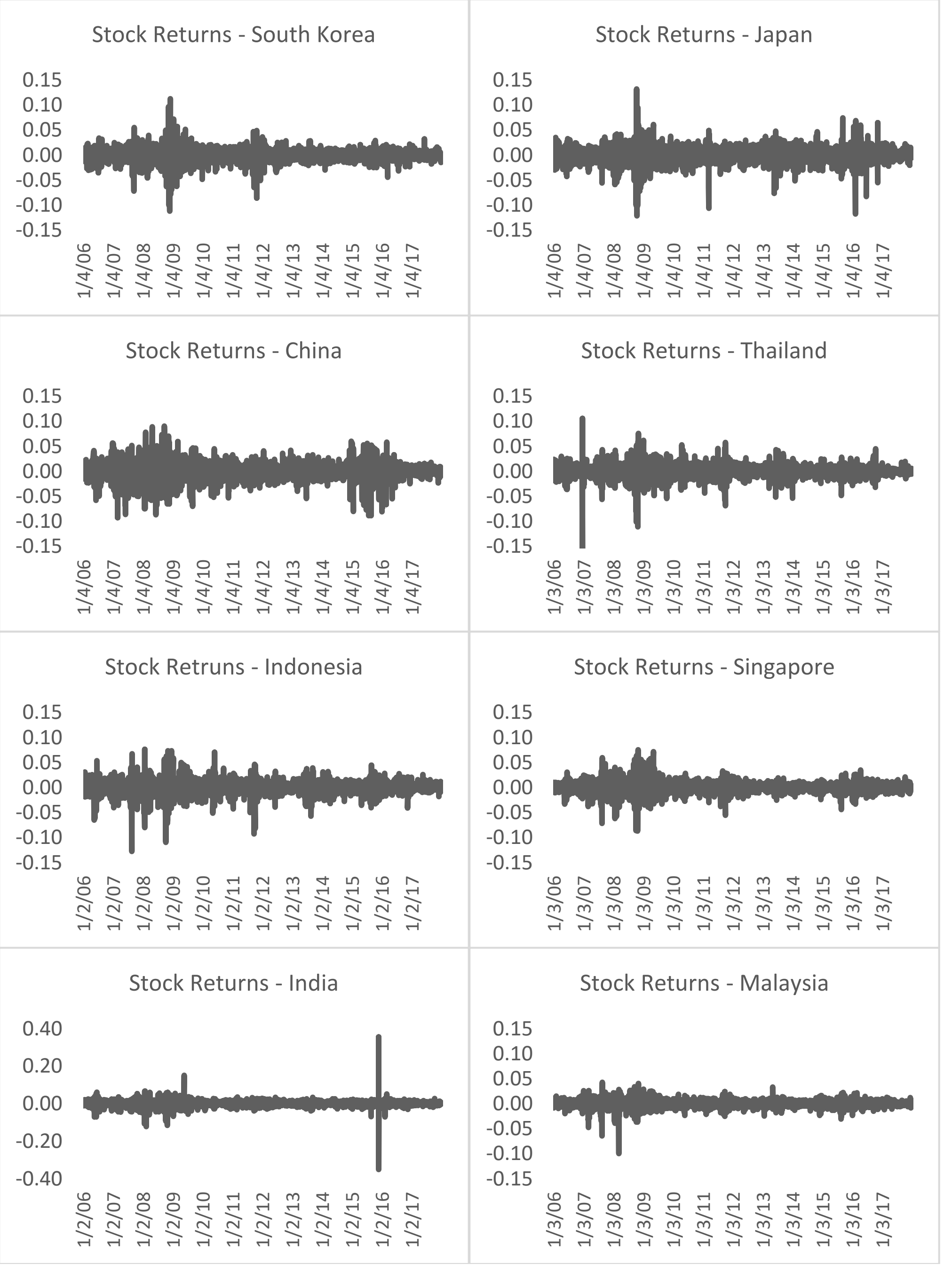

Figure 1. Stock Market Returns

5. Empirical Results

Table 3 and Table 4 show the results of return correlations based on the Fisher's Z transformation. The second column shows return correlations between the South Korean stock market and the other Asian stock markets for the pre-test period. As mentioned in the data section, we split the post-test period into four different sub-periods: post 5-day, post 10-day, post 15-day, and post 20-day periods.

Table 3. Correlation Changes after 1st, 2nd, and 3rd Nuclear Tests

Panel A: 1st Nuclear Test (October 9, 2006)					
Country	Pre 90-Day Correlation	Post 5-Day Correlation	Post 10-Day Correlation	Post 15-Day Correlation	Post 20-Day Correlation
Japan	0.8419	-0.5071**	-0.3014**	0.0329**	0.0149**
China	0.2232	0.0429	0.1033	-0.0098	0.0102
Thailand	0.6143	0.2621	0.5232	0.6831	0.6062
Indonesia	0.6827	0.6604	0.3118	0.0834**	0.2768*
Singapore	0.7804	0.8059	0.6915	0.7738*	0.7129
India	0.5568	0.6580	0.7376	0.2020	0.2637
Malaysia	0.4900	0.6219	0.6899	0.5183	0.5861
Panel B: 2nd Nuclear Test (May 15, 2009)					
Country	Pre 90-Day Correlation	Post 5-Day Correlation	Post 10-Day Correlation	Post 15-Day Correlation	Post 20-Day Correlation
Japan	0.7609	0.3207	0.5846	0.7167	0.6261
China	0.4384	0.8488	0.6224	0.3804	0.3599
Thailand	0.5275	0.4010	0.1967	0.3551	0.3856
Indonesia	0.6018	0.5647	0.4368	0.2822	0.3409
Singapore	0.5798	0.1331	0.3073	0.3878	0.4303
India	0.3859	0.4555	0.1969	0.1815	0.1970
Malaysia	0.5142	0.2328	0.0699	0.2660	0.2704
Panel C: 3rd Nuclear Test (February 12, 2013)					
Country	Pre 90-Day Correlation	Post 5-Day Correlation	Post 10-Day Correlation	Post 15-Day Correlation	Post 20-Day Correlation
Japan	0.3640	-0.4715	0.0613	0.1380	0.1175
China	0.2346	0.8667	0.5951	0.4900	0.4640
Thailand	0.3277	0.8531	0.7475	0.7226*	0.6985*
Indonesia	0.2347	0.4706	0.4170	0.4688	0.4102
Singapore	0.5215	0.8675	0.7305	0.6119	0.4774
India	0.2847	-0.0687	0.43331	0.0698	-0.0135
Malaysia	-0.01379	0.9047*	0.1179	0.2816	0.2451

Note: * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Table 4. Correlation Changes after 4th, 5th, and 6th Nuclear Tests

Panel A: 4th Nuclear Test (January 6, 2016)					
Country	Pre 90-Day Correlation	Post 5-Day Correlation	Post 10-Day Correlation	Post 15-Day Correlation	Post 20-Day Correlation
Japan	0.5804	0.9397	0.8596	0.9053**	0.8257*
China	0.3793	0.6690	0.4124	0.5043	0.3792
Thailand	0.4128	0.8128	0.8171*	0.7706*	0.7376*
Indonesia	0.5262	0.7804	0.6669	0.7395	0.7335
Singapore	0.4763	0.8764	0.8142	0.8517**	0.7516*
India	0.0825	0.7552	0.7055*	0.8117**	0.7810**
Malaysia	0.5933	0.8032	0.7339	0.7733	0.6855
Panel B: 5th Nuclear Test (September 9, 2016)					
Country	Pre 90-Day Correlation	Post 5-Day Correlation	Post 10-Day Correlation	Post 15-Day Correlation	Post 20-Day Correlation
Japan	0.6746	0.3788	0.5659	0.4600	0.4593
China	0.3505	0.9918**	0.8434*	0.5579	0.5218
Thailand	0.3069	0.7277	0.6641	0.6647	0.4900
Indonesia	0.4036	0.7984	0.7615	0.7360*	0.6497
Singapore	0.6771	0.9076	0.8696	0.8553	0.7254
India	0.5630	0.9306	0.4948	0.3323	0.4432
Malaysia	0.4899	0.1443	0.1376	0.3462	0.2480
Panel C: 6th Nuclear Test (September 3, 2017)					
Country	Pre 90-Day Correlation	Post 5-Day Correlation	Post 10-Day Correlation	Post 15-Day Correlation	Post 20-Day Correlation
Japan	0.6117	0.8559	0.5395	0.5797	0.5027
China	0.1396	-0.9693**	-0.6635*	-0.2889	-0.1466
Thailand	0.1754	0.8886*	0.6743	0.7448**	0.6643**
Indonesia	0.2355	0.7166	0.7027	0.5807	0.5460
Singapore	0.3820	0.6208	0.5559	0.5802	0.4688
India	0.2837	0.7106	0.6474	0.6835*	0.6190
Malaysia	0.3930	0.7898	0.3491	0.3908	0.3711

Note: * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Since Lim (2012) and Huh and Pyun (2018) show that the impact of North Korea's nuclear tests tends to last only for several days, the post 5- and 10-day correlations provide strong evidence, whereas the post 15- and 20-day correlations provide only weak evidence. During the pre-test periods, the Japanese stock market and the Singapore stock market tend to be highly correlated with the South Korean stock market, whereas Chinese stock market, Indian stock market, Malaysian stock market, and Thailand stock market tend to be slightly correlated with the South Korean stock market.

On the whole, North Korea's nuclear tests do not appear to have frequent and wide impacts on Asian stock markets. With the post 5- and 10-day correlations as strong evidence, the Chinese stock market, and the Thailand stock market turn out to be a little more significantly affected by relatively recent nuclear tests than the other Asian stock markets. In addition, the Chinese stock market has some reflective effect from the sixth nuclear test because its post 5- and 10-day correlations are significantly negative. This means the Chinese stock market's surge during the South Korean stock market's significant daily pullback (-1.2%) right after the sixth nuclear test. Although Japan is geographically close to North Korea and is politically vigilant to North Korea's nuclear tests, its stock market does not have any significant correlation change except only for the first nuclear test as a first unexpected shock.

On the other hand, the post 15- and 20-day correlations show slightly different results. All significant correlation changes are positive, and the Thailand stock market has relatively more significant changes than the other Asian stock markets. However, as mentioned above, the post 15- and 20-day results would be regarded only as weak evidence because the post 15- and 20-day effects are likely to be quite diluted and dominated by other market noises.

Next, Tables 5, 6, and 7 show volatility results. First, with the post 10-day results as strong evidence, we find that some countries have opposite signs for significant volatility changes compared to significant correlation changes based on the Fisher's Z transformation. For example, while the Indian stock market has a significant positive correlation change during the post-test period of the 4th nuclear test, it has a significant negative volatility change during the post-test period of the same nuclear test.

Table 5. Volatility Changes after 1st and 2nd Nuclear Tests

Panel A: 1st Nuclear Test								
	Post 10-Day				Post 20-Day			
Dep. Var	β_0	β_1	θ_1	γ_{NT}	β_0	β_1	θ_1	γ_{NT}
Japan	0.000343**	0.072961	-0.904470**	0.687650**	0.000261	-0.004128	-0.487450	0.121170
China	0.000050**	0.027017	-0.617320	-0.149600**	0.000157	-0.040106**	-0.093540	-0.976070**
Thailand	0.000006	0.019757	0.921190**	-0.253140	0.000041**	0.056586	0.619340**	-0.737350**
Indonesia	0.000243	0.079276	-0.180080	-0.782810	0.000252**	0.117790	-0.284290	-1.065700**
Singapore	0.000002	0.022201	0.929340**	0.010380	0.000001	0.007035	0.953330**	0.092314
India	0.000009	0.083411	0.861960**	-0.408270	0.000046**	0.193110*	0.692280**	-1.266200**
Malaysia	0.000022**	0.190600	-0.280940	0.133870	0.000023**	0.191450	-0.385390	0.290870
Panel B: 2nd Nuclear Test								
	Post 10-Day				Post 20-Day			
Dep. Var	β_0	β_1	θ_1	γ_{NT}	β_0	β_1	θ_1	γ_{NT}
Japan	0.000769	-0.001568	-0.540460	-0.096846	0.000077	0.010441	0.824020**	-0.208200
China	0.000451	-0.128080**	-0.070547	0.146730	0.000557**	-0.063109	-0.604380	0.066726
Thailand	0.000430**	-0.116100**	-0.519540**	0.377920**	0.000490**	-0.054424	-0.717770**	0.351330
Indonesia	0.000281**	0.414680**	-0.290740	0.232360	0.000299**	0.247550	-0.291250	0.400110
Singapore	0.000891**	0.007822	-0.897050**	-0.392130	0.000819**	0.019239**	-0.854560**	-0.273800
India	0.000260	-0.016125	0.213200	-0.087738	0.000478*	0.273750*	-0.138790	-0.065058
Malaysia	0.000122	-0.101150	-0.246280	-0.050111	0.000180**	-0.046827	-0.910950**	0.137650**

Note: * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Table 6. Volatility Changes after 3rd and 4th Nuclear Tests

Panel A: 3rd Nuclear Test								
	Post 10-Day				Post 20-Day			
Dep. Var	β_0	β_1	θ_1	γ_{NT}	β_0	β_1	θ_1	γ_{NT}
Japan	0.000291**	-0.006518	-0.849170**	-0.041658	0.000284**	-0.004507**	-0.856540	0.059363
China	0.000292**	0.028560	-0.982910**	-0.049071	0.000277**	0.055066	-0.953290**	-0.068174
Thailand	0.000078**	-0.004606	-1.006600**	0.016608	0.000025	0.000804	0.222490	0.382440
Indonesia	0.000005	0.152580	0.664370	0.006805	0.000005	0.181160	0.681040**	0.051299
Singapore	0.000034**	0.128540	-0.68992*	0.023388	0.000014	-0.081920	0.484480	0.054863
India	0.000078**	0.019090	-0.671930	-0.029741	0.000079**	-0.088816	-0.420140	-0.139780**
Malaysia	0.000006	-0.035520**	0.728430**	-0.016958	0.000010**	-0.094435**	0.438210	-0.043588
Panel B: 4th Nuclear Test								
	Post 10-Day				Post 20-Day			
Dep. Var	β_0	β_1	θ_1	γ_{NT}	β_0	β_1	θ_1	γ_{NT}
Japan	0.000094*	0.554640*	0.214850	1.217000	0.000011	0.123760	0.828080**	0.402000
China	0.000170	0.234810	0.546060*	-1.199400**	0.000109	0.078501	0.680230**	1.540100
Thailand	0.000033	0.036327	0.606500	0.331560	0.000042	0.004338	0.482870	1.071600
Indonesia	0.000227	0.108590	-0.344940	-0.032375	0.000196*	0.116070	-0.255730	-0.061266
Singapore	0.000025	0.006231	0.661540**	0.283630	0.000028	0.003489	0.645410**	0.509960
India	0.001977**	0.253880	-0.29427	-2.404200**	0.001647*	0.177680	-0.184510	-1.916200**
Malaysia	0.000002	0.111510	0.845060**	0.037924	0.000003	0.114110	0.845710**	0.043935

Note: * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Table 7. Volatility Changes after 5th and 6th Nuclear Tests

Panel A: 5th Nuclear Test								
	Post 10-Day				Post 20-Day			
Dep. Var	β_0	β_1	θ_1	γ_{NT}	β_0	β_1	θ_1	γ_{NT}
Japan	0.000452**	0.028354	-0.851680**	-0.171660	0.000424**	0.033784**	-0.876440**	-0.211130
China	0.000076**	-0.063114**	-0.043727	0.285780	0.000046	-0.061920**	0.361120	0.078606
Thailand	0.000042**	0.491970*	-0.160260	0.020503	0.000014	0.030736	0.684380**	0.943480
Indonesia	0.000072	0.097598	-0.263570	0.010537	0.000067*	0.157870	-0.242090	0.166020
Singapore	0.000051	0.035277	0.036884	0.433440	0.000045	0.033700	0.121740	0.221080
India	0.000014	-0.035190	0.764320	0.011496	0.000033	-0.062629	0.338770	0.293180
Malaysia	0.000027**	-0.110880**	-0.075458	0.156730*	0.000040**	-0.130770**	-0.303730**	0.049046
Panel B: 6th Nuclear Test								
	Post 10-Day				Post 20-Day			
Dep. Var	β_0	β_1	θ_1	γ_{NT}	β_0	β_1	θ_1	γ_{NT}
Japan	0.000028*	0.264120	0.014539	0.259120	0.000026*	0.265510	0.012143	0.145190
China	0.000068**	-0.000926	-1.023800**	-0.193390*	0.000050**	0.027017	-0.617320	-0.149060**
Thailand	0.000011	0.074327	0.039254	-0.021070	0.000013**	0.124670	-0.227150	-0.105030**
Indonesia	0.000056**	-0.046606**	-0.486360	0.307910	0.000001	-0.037998	1.012000**	-0.049067*
Singapore	0.000047**	0.129830**	-1.017200**	0.223680**	0.000036**	0.157160*	-0.527160*	0.353520
India	0.000020*	0.369620*	0.118820	-0.047589	0.000012	0.240390	0.442890	0.301950
Malaysia	0.000012*	0.139680	-0.374190	0.035615	0.000011**	0.192520	-0.323430	0.004318

Note: * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Since the correlation shows the degree of the linearity between two different stock markets' returns regardless of the size of return changes, the strengthened positive linearity (significant positive correlation change) doesn't seem to be necessarily related to a significant volatility increase. In other words, during the post-test period of the 4th nuclear test, the volatilities of the Indian stock market decrease relative to those of the South Korean stock market though the linearity (correlation) between these two stock markets' returns is positively strengthened.

Second, the Chinese stock market experienced significant volatility changes more frequently than the other Asian stock markets. However, its significant dummy coefficients (γ_{NT}) are all negative, which means that the volatilities of the Chinese stock market decrease relative to those of the South Korean stock market during those post-test periods.

The volatilities of the other Asian stock markets appear to be not much affected. On the other hand, the post 20-day results show more significant changes than the post 10-day results. However, again, these results are regarded as just weak evidence because of the same reason mentioned in our correlation analysis.

6. Conclusion

Although many studies deal with North Korea's military threats, most of them focus on a political or international point of view. Only a few studies investigate the financial impact of North Korea's nuclear tests on the South Korean stock market, and overall, it is shown that those nuclear tests substantially influence the South Korean stock market. However, no studies look into the impact of North Korea's nuclear tests on Asian stock markets other than the South Korean stock market. While South Korea is most immediately and directly affected by North Korea's nuclear tests, not every Asian country may be directly impacted by the nuclear tests. Thus, with the South Korean stock market as a base stock market, we examine if North Korea's nuclear tests have an impact on Asian stock markets by identifying return and volatility movements of Asian stock markets relative to those of the South Korean stock market.

First, we see if there is any significant change in the return correlation between the South Korean stock market and the other Asian stock markets immediately after the nuclear tests. While Asian stock markets do not appear to be frequently and widely impacted by North Korea's nuclear tests, the Chinese stock market and the Thailand stock market tend to be relatively more affected by recent nuclear tests than the other Asian stock markets. Although Japan is geographically close to North Korea, its stock market is little affected by the nuclear tests. One possible explanation for this would be that the Japanese market is likely to be equipped with more hedging mechanisms or stable capital flows as one of the most developed markets. Second, we investigate volatility changes triggered by the nuclear tests from the South Korean stock market to the other Asian stock markets. We find that the Chinese stock market experienced relatively more significant volatility changes than the other

Asian stock markets, and those significant changes are all negative, which means that the volatilities of the Chinese stock market tend to decrease relative to those of the South Korean stock market after the nuclear tests. In fact, with our correlation results, this implies that the strengthened linearity (significant correlation change) is not necessarily related to a significant volatility increase. As a result, both return and volatility tests show that the Chinese stock market tends to be relatively more influenced by North Korea’s nuclear tests than the other Asian stock markets.

Lastly, our study might have one limitation due to some other events or factors that can affect stock return movements. However, since North Korea’s nuclear tests typically make top breaking news headlines, we believe that North Korea’s nuclear tests should dominate for a short period of time immediately after the nuclear tests. Nevertheless, if other events or factors are to be considered, further research would be needed.

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