Examining Volatility Spillover Effect from the United States Stock Market to the Taiwan Stock Exchange

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ABSTRACT

This paper investigates the impact of the United States stock market on the Taiwanese stock market. It estimates the spillover and leverage effects of returns and volatility of three United States stock indices and a Taiwan stock index using asymmetric ARMA-M-TGARCH and ARMA-M-EGARCH. According to the findings, there is a spillover impact between the United States stock market and the Taiwan stock market, implying a directional volatility relationship. There is evidence of unequal responses to their own market's negative shocks. The indication of earlier shocks has an impact on the conditional variance. Because "bad news" has a greater impact on volatility, we would expect a negative asymmetric volatility influence on leverage effect in the ARMA-M-EGARCH model. The results show a large negative asymmetric volatility effect. On the other hand, the leverage effect of the ARMA-M-TGARCH model was positive, showing that prior shock impacts are real.

Keywords: GARCH; Leverage Effect; Spillover Effect; Stock Market.

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1. INTRODUCTION

The impact of seemingly unrelated events within a single country on the economies of other countries is known as the "spillover effect". While there are considerable spillover effects, the phrase is most commonly used to describe the negative impact that an internal event, such as a catastrophe, disaster, financial collapse, or other global events, has on particular areas of the market. Taiwan's economy is centered on technological gear. The trade war between the United States and China, which began in March 2018, has significantly benefited Taiwan. Increased United States taxes on Chinese-made items prompted Taiwanese electronics companies to bring manufacturing back home, which is regarded as more competitive and cost-effective than seeking for overseas production sites.

According to the distribution of countries with the highest capital markets worldwide as of January 2021, by share of overall world equity market size, Taiwan is ranked 11th by 1.7 percent, and the United States stock market is ranked first by 55.9 percent.

The United States is Taiwan's most significant commercial partner and one of its primary export markets. Taiwan's main export market and second-largest source of imports in 1990 was the United States. Zhang et al (2021) noted that as of December 2020, the United States' total investment in Taiwan amounted to US$24.87 billion, becoming the United States Taiwan's third-largest source of FDI and the greatest donor of technology for the main sectors. The United States investment not only contributes technology and managerial know-how, but

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also cultivates Taiwanese business leaders and aids in the integration of Taiwanese firms into global supply networks.

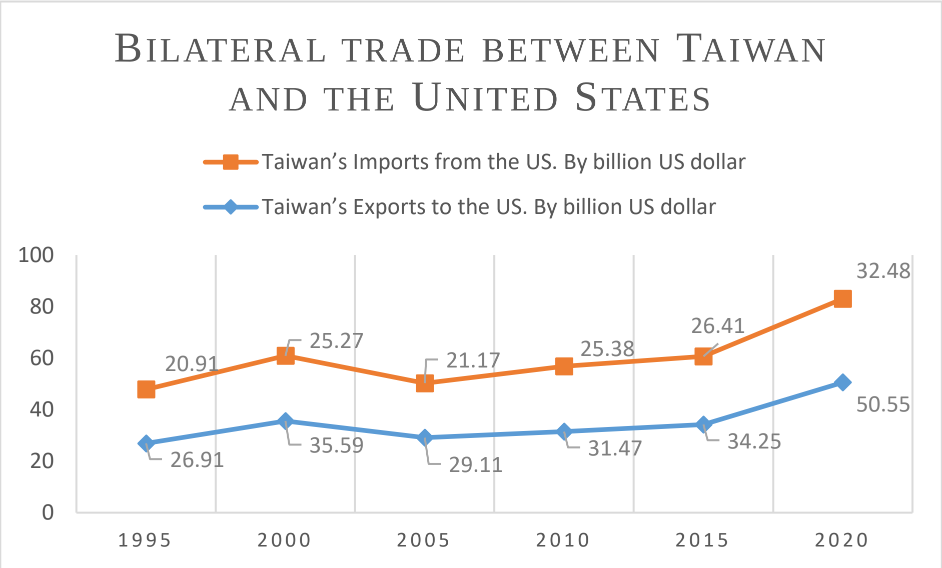

Figure 1. Bilateral trade between Taiwan and the United States.

Taiwan had invested US$22.15 billion in the United States as of December 2020, and the United States is Taiwan's second-largest foreign investment destination. Today, the United States and China have the world's two largest economies. Although there are substantial disparities between the two nations in many economic fields, the connection of the two countries' financial sectors has progressively strengthened. As a result of the trade war between the United States and China in 2018, the stock markets in both China and the United States had daily declines of more than 3% on many occasions, causing fear in the global financial market. Because of the close relationship between Taiwan and the United States financial markets, as well as the disjoint trading hours, information from the recently closed the United States market can be used to predict the next opened Taiwan market, the time-shift property is used to predict the Taiwan stock market's trend based on data from the United States stock market.
Wu et al (2012) recognized S&P500 index (Standard & Poor's 500) in the United States is made up of 500 of the most important companies in the United States, the most important benchmark index for investors to recognize stock market results, trends, and decisions although researchers expected to make certain contributions and aid Taiwanese in the selection of their investment portfolio.

There is a form of network effect that has increased after trade and stock market globalization strengthened economic-to-economy financial linkages. Commercial partnerships such as the United States - Taiwan provide an example of spillover consequences. That is because the United States is produce the best results for Taiwan by international relationship and cooperation, Taiwan's concentration on the United States economy for its success amplifies the impact of a slight downturn in the United States.

This research aimed to analyze the Taiwanese Stock Exchange, the impact of the volatility spillover financial markets in the United States. The literature includes research that has explored the Taiwanese Stock Exchange's long-term association with the United States market.

2. RELATED LITERATURE REVIEW

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Wei et al (1995) considered three developed markets, New York, Tokyo, and London, and they investigate two emerging markets, Taiwan and Hong Kong. The study revealed that the Taiwanese market is sensitive to the price and volatility influence of the advanced markets. Liu and Pan (1997) studied the mean "spillover effects" of return and volatility from the United States and Japan to Hong Kong, Thailand, Singapore, and Taiwanese markets. The observational findings from the analysis of the evidence for the period 1984 to 1991, which indicates that the United States economy is affecting the four Asian economies and that the spillover effects found are unpredictable over time. Joshi (2011) used a six-variable asymmetric (GARCH-BEKK) model to analyze the "spillover effect" in return and volatility among Asian stock markets in India, Hong Kong, Japan, China, Jakarta, and Korea. Sheu and Cheng (2011) evaluated the insignificant effects of China and the United States stock market fluctuations on Taiwan and Hong Kong using vector autoregressive (VAR) and multivariate generalized autoregressive conditional heteroskedastic (MGARCH) models: 1996-2005 and 2006-2009. Lee (2013) finds that the BWCARR models are better than the two CARR models themselves. There are the "spillover effects" of frequency-based instability, suggesting the presence of a frequency of spillovers from the United States and Japan that affect the Taiwan market. Peng et al (2017) found co-integrated relation, which indicates a long-term, stable relationship between the Taiwanese and Japanese capital markets, and analyzed the "spillover effect" of volatility using the Taiwan Capitalization Weighted Market Index (TAIEX) and the NIKKEI Stock Average Index (NIKKEI) benchmarks. In two distinct sub-periods, Chan et al (2017) showed the "spillover effect" of bidirectional volatility, and the cross-market leverage effect remains between the index options and their underlying United States, UK, Taiwan markets using GARCH-BEKK and GARCH DCC models.

3. METHODOLOGY

Majority of past studies advocated the use of the GARCH model to analyze volatility spillover across stock markets. Autoregressive conditional heteroskedastic (ARCH) and generalized autoregressive conditional heteroskedastic (GARCH) models are used to quantify the complex relationship of a process's volatility. Engle (1982) presented ARCH models, which Bollerslev (1986) simplified as GARCH. These models have become common methods for working with time-series heteroskedasticity, and they are increasingly being used to model the systematic risk of financial series.

The study used Chen and Diaz (2019) two asymmetric GARCH models to evaluate the "spillover effect" from the United States stock market to the Taiwan Stock Exchange.

This study used log returns to examine daily returns.

$$R_{j,t} = \ln\left(\frac{P_{j,t}}{P_{j,t-1}}\right) \qquad (1)$$

Here $P_{j,t}$ is the closing index of each trading day of j^{th} company.

The "spillover effect" ARMA-M-TGARCH:

$$R_{i,t}^{c} = \alpha_0 + \sum_{i=1}^{g} \alpha_1 R_{i,t-i}^{c} + \gamma N_{t-i}^{c} + w R_{t-1}^{m} + \varepsilon_{i,t}^{c} + \sum_{i=1}^{s} \theta_i \varepsilon_{i,t-i}^{c}$$

$$N_{t-i}^{c} = \{1 \text{ if } \alpha_{t-i} < 0 \text{ or } 0 \text{ if } \alpha_{t-i} \geq 0\} \qquad (2)$$

The "spillover effect" ARMA-M-EGARCH:

$$R_{i,t}^{c} = \alpha_0 + \sum_{i=1}^{g} \alpha_1 R_{i,t-i}^{c} + w R_{t-1}^{m} + \varepsilon_{i,t}^{c} + \sum_{i=1}^{s} \theta_i \varepsilon_{i,t-i}^{c}$$

$$\log(h_{i,t}^{c^2}) = a + \sum_{i=1}^{p} (a_1 \left| \frac{\varepsilon_{i,t-i}^{c}}{h_{i,t-i}^{c}} \right| + \delta_1 \frac{\varepsilon_{i,t-i}^{c}}{h_{i,t-i}^{c}}) + \sum_{i=1}^{q} \psi_i \log(h_{i,t-i}^{c^2}) \ , \ \varepsilon_{i,t}^{c} | \psi_{t-1} \sim N(0, h_{i,t}^{c}) \qquad (3)$$

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Here
$\sum_{i=1}^{g} \alpha_1 R_{i,t-i}^{c}$ higher order of the autoregressive AR(g)
$\varepsilon_{i,t}^{c}$ returns residual at the period *t*
$\sum_{i=1}^{s} \theta_i \varepsilon_{i,t-i}^{c}$ higher order moving average mean process MA(s) at the period *t*
$\sum_{i=1}^{q} a_1 \varepsilon_{i,t-i}^{c^2}$ q order of the ARCH term at the period *t*
$\sum_{i=1}^{p} \psi_i h_{i,t-i}^{c}$ p order conditional heteroscedasticity of EGARCH term at period *t*
γN_{t-i}^{c} TGARCH parameter
w the United States "spillover effect" parameter
δ_1 leverage term
θ_i unknown parameter

4. RESULTS OF THE STUDY

This study uses daily data of the Taiwanese Stock Exchange TAIEX period of 17 Jul 2017 to 17 Jul 2020. All data were downloaded from the official website of the Taiwanese Stock Exchange.

Table 1. Descriptive statistics of the Taiwan Stock Exchange index TAIEX.

Mean	**0.00021**	**Kurtosis**	**12.9518**
Median	0.00035	Jarque-Bera	3204.9371
Maximum	0.0637	Probability	0.0000
Minimum	-0.0631	Sum	0.1641
Std. Dev.	0.00977	Sum Sq. Dev.	0.0716
Skewness	-0.90075	Observations	752

The summary statistics of the returns series as reported in Table 1 that present TAIEX daily returns or changes lie between -0.0631 and 0.0637 with the mean of 0.00021. The standard deviation is small, which suggests that stable changes occur in daily trade in the Taiwanese Stock Exchange.

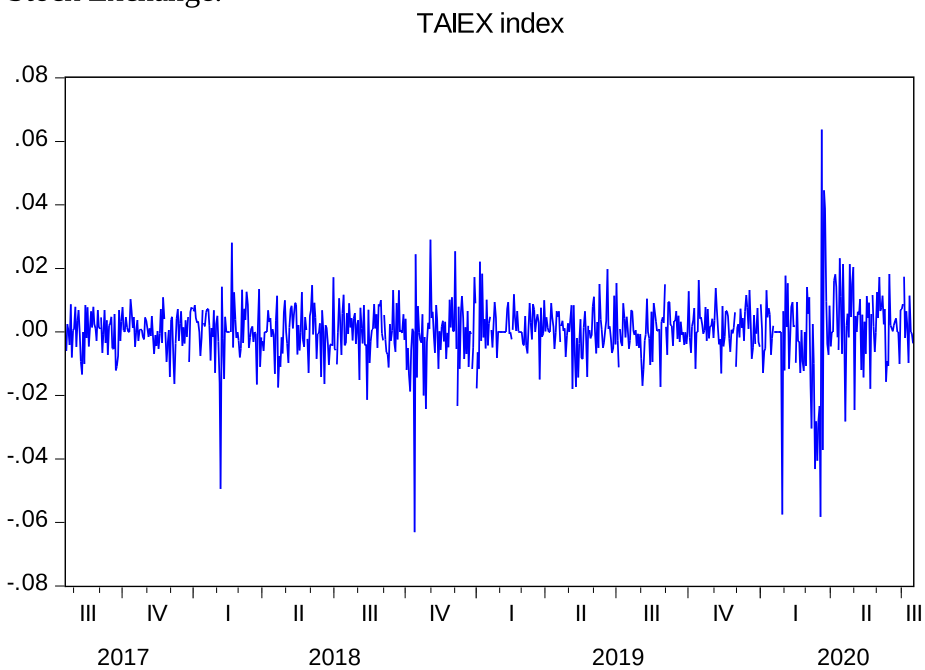

Figure 2. TAIEX index daily returns or changes.

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We assume TAIEX 's daily returns from Figure 2 are stationary. The most intuitive sense of stationarity means that a method producing a time series does not alter the statistical properties over time. Stationarity in time series data analyzes has been a standard concept for many methods. These include, among others, trend modeling, prediction, etc.

Table 2. Unit root test for stationarity of TAIEX.

Null Hypothesis: TAIEX has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=19)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-16.97226	0.0000
Test critical values:	1% level	-3.438819	
	5% level	-2.865168	
	10% level	-2.568757	

A unit root is a stochastic pattern in a time-series data, it indicates a systematic trend and is random because a time series has a unit root. If a time series does not induce a difference in the form of the distribution, a time series has stationarity. The Augmented Dickey-Fuller or ADF test is based on linear regression which is broadly used for time series data with serial correlation issues. The null hypothesis in the Augmented Dickey-Fuller test statistic is expecting unit root with exogenous data. Table 2 presents TAIEX daily returns have unit root and which interpreted as the study data is stationarity for all levels of confidence, we may use the data to continue to investigate Autoregressive Moving Average (ARMA) modeling.

Table 3. Autoregressive Moving Average model selection matrix

AR/MA	0	1	2	3
0	-6.4176	-6.4155	**-6.4351**	-6.4346
1	-6.4149	-6.4164	-6.4335	-6.4311
2	-6.4317	-6.4310	-6.4298	-6.4271
3	-6.4306	-6.4289	-6.4258	-6.4324

Choosing the best ARMA model for the study requires generating Akaike Information Criterion (AIC) matrix of 0-3 orders. The lowest scalar would be chosen for the best fitted ARMA model. ARMA (0,2) order model is the most suited one regarding Table 3 presentation. Here, AR attempts to explain the momentum and mean reversal effects frequently observed in trading markets, MA aims to capture the effects of shock observed shock effects could be considered as unforeseen events affecting the process of observation.

Table 4. Breusch-Godfrey Serial Correlation LM Test of TAIEX

Breusch-Godfrey Serial Correlation LM Test

F-statistic	0.788575	Prob. F(2,747)	0.4549
Obs*R-squared	1.584361	Prob. Chi-Square(2)	0.4529

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Increased index volatility or rates of return volatility are often indicators that the variances are not constant over time. Engle (1982) introduced a new modeling approach to heteroscedasticity in the context of a time series. Autoregressive Conditional Heteroskedasticity (ARCH) models are designed specifically for modeling and predicting conditional variances. Two distinct requirements when designing an ARCH model: conditional mean and conditional variance. We expect having the statistically insignificant result of failing to reject the null hypothesis, i.e., no serial correlation. Breusch-Godfrey Serial Correlation LM Test from Table 4 is insignificant, which we accept the null hypothesis, i.e., TAIEX has no serial correlation issue.

Table 5. Heteroskedasticity Test of TAIEX.

		Heteroskedasticity Test: ARCH	
F-statistic	39.37951	Prob. F(2,747)	0.0000
Obs*R-squared	71.5333	Prob. Chi-Square(2)	0.0000

We conduct an ARCH-LM test to check the autoregressive conditional effect in TAIEX daily returns. In this test, the null hypothesis is that there is no ARCH effect whereas an alternative effect is that there is an ARCH effect. The ARCH effect test results are presented in Table 4. ARCH LM's heteroscedasticity test, which is significant, indicating that there is no effect of ARCH, and therefore we can proceed to the GARCH Model.

Table 6. GARCH (p,q) order selection.

q/p	**1**	**2**	**3**
1	-6.6401	-6.6375	-6.6358
2	-6.6376	-6.6349	-6.6333
3	-6.6397	-6.6358	**-6.6529**

In terms of building a strong GARCH model, it is necessary to check the orders of ARCH effect. We examine GARCH (p,q) based on the lowest AIC from the matrix. The GARCH (3,3) model is chosen in this study, which is presented Table 6. The GARCH (3,3) is a higher-order model that is also helpful when using a large data interval, such as several years of daily data, and allows information to deteriorate quickly and slowly with additional lags.

Table 7. The Spillover effect and the leverage effect of the Taiwan Stock Exchange index TAIEX.

ARMA-M-TGARCH

Spillover Effect of Return			Spillover Effect of Volatilities	Return on Risk	Leverage Effect
S&P500	NASDAQ	DOW JONES			
-1.0154	0.6546	0.6416	0.4356	-0.0768	0.3026
0.0000***	0.0000***	0.0000***	0.0000***	0.6797	0.0000***

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ARMA-M-EGARCH

Spillover Effect of Return			Spillover Effect of Volatilities	Return on Risk	Leverage Effect
S&P500	NASDAQ	DOW JONES			
-0.1438	0.3194	0.1393	7672.6440	-0.1348	-0.2478
0.4793	0.001***	0.2395	0.0000***	0.3273	0.0000***

According to Xiong and Han (2015), the financial markets' volatility "spillover effect" has long been a focus of the financial supervision regulation department and academics both at home and abroad. ARMA(0,2)-M-TGARCH(3,3) and ARMA(0,2)-M-EGARCH(3,3) models were examined for the United States stock market to the Taiwanese Stock Exchange. For the terms of return on volatilities (mean regressor of M), we were using the standard deviation of TAIEX daily returns. We found negative "spillover effect" from S&P500 to TAIEX from both models but ARMA-M-EGARCH model failed with showing the insignificant results. S&P500 has a strong a negative effect (-1.0154) on TAIEX.

NASDAQ index has a significant positive relation with TAIEX on both models. DOW JONES's "spillover effect" of return shows a significant positive effect TAIEX in ARMA-M-TGARCH model, but ARMA-M-EGARCH model performed insignificantly.

Estimating the value of volatility spillover implies that the influence of United States stock indices fluctuations on the TAIEX is great and the result provides that both ARMA-M-TGARCH and ARMA-M-EGARCH models have positive "spillover effect" on volatilities. The "spillover effect" on volatilities is significantly different from zero which indicates a tight linkage between the United States stock market and the Taiwanese stock market.

For the terms of ARCH-M, the relationship between risk and return on the stock is negatively associated with TAIEX. Such return on risk differences indicate that an increase in risk enhances the expected return – low uncertainty and low risk levels are associated with low potential returns; high uncertainty and high risk levels are associated with high potential returns.

We would generally predict a negative asymmetric volatility influence on leverage effect in ARMA-M-EGARCH model because "bad news" has a stronger impact on volatilities and the result reveal a strongly negative asymmetric volatility effect. On the other hand, ARMA-M-TGARCH model's "leverage effect" is positive, which indicates that the impacts of past shocks are real. The threshold variable takes into consideration the effect of the association between conditional variance and other observed variables reflecting TAIEX index adjustments.

5. CONCLUSIONS

Various ARMA-M-TGARCH and ARMA-M-EGARCH models were used in this study to calculate the spillover and leverage effect of returns and volatility of three United States stock indices and one Taiwanese stock index. The study found a "spillover effect" from the United States stock market to the Taiwanese stock market.

The lagged S&P 500 index has a negative effect on TAIEX daily returns in both the ARMA-M-TGARCH and ARMA-M-EGARCH models. The lagged NASDAQ and DOW JONES indices positively affect TAIEX index. From the empirical result, we suggest the ARMA-M-TGARCH model for the United States market's spillover to the Taiwanese stock exchange. This study finds a directional volatility linkage between the United States market and the Taiwan market.

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For the TAIEX, we find evidence of asymmetric responses to the negative shocks of own market. This indicates that past shocks influence the conditional variance. We normally expect a negative asymmetric volatility influence on the leverage effect in the ARMA-M-EGARCH model because “bad news” has a greater impact on volatility and the results show a large negative asymmetric volatility effect. The leverage effect of the ARMA-M-TGARCH model, on the other hand, was positive, indicating that the effects of previous shocks exists.

This study provides scholars and analysts with a new awareness of how the United States stock market influences other stock markets around the world. Due to Taiwan's existing political and diplomatic status in the international arena, there are not many proactive measures that Taiwan can instantly implement when dealing with the consequences of the current US-China trade tensions. However, a detrimental impact on Taiwan is unavoidable. Aside from regional trade agreements if nothing is done. Bilateral free trade agreements would be an alternate trade deal for Taiwan as it has unique and difficult political, economic, and military relationships with both the United States and China.

REFERENCES

[1] Bollerslev, T. (1986). “Generalized autoregressive conditional heteroskedasticity”. *Journal of Econometrics*, 31, 307–327.10.1016/0304-4076(86)90063-1

[2] Chan, C.-Y., Peretti, C. de, Wang, M.-C., & Chen, H.-M. (2017). “The Volatility Spillover Effect between Index Options and their Underlying Markets: Evidence from the US, the UK, and Taiwan”. *Asia-Pacific Journal of Financial Studies*, 46(5), 700–733.

[3] Chen, Jo-Hui & Diaz, John Francis. (2019). “The Spillover and Leverage Effects of Equity Exchange-traded Notes (ETNs)”. *Global Economy Journal*. 19. 1-17. 10.1142/S2194565919500131.

[4] Engle, R. F. (1982). ”Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation”. *Econometrica*, 50, 987–1007.10.2307/1912773

[5] John Wei, K. C., Liu, Y.-J., Yang, C.-C., & Chaung, G.-S. (1995). “Volatility and price change spillover effects across the developed and emerging markets”. *Pacific-Basin Finance Journal*, 3(1), 113–136.

[6] Joshi, P. (2011). “Return and Volatility Spillovers Among Asian Stock Markets”. *SAGE Open*, 1(1), 2158244011413474.

[7] Lee, Y.-H. (2013). “Global and regional range-based volatility spillover effects”. *Emerging Markets Review*, 14, 1–10.

[8] Liu, Y., & Pan, M.-S. (1997). “Mean and Volatility Spillover Effects in the United States and Pacific-Basin Stock Markets”. *Multinational Finance Journal*, 1.

[9] Peng, C. L., Chung, C.-F., Tsai, C.-C., & Wang, C.-T. (2017). “Exploring the Returns and Volatility Spillover Effect in Taiwan and Japan Stock Markets”. *Asian Economic and Financial Review*, 7, 175–187.

[10] Sheu, H.-J., & Cheng, C.-L. (2011). “A study of United States and China’s volatility spillover effects on Hong Kong and Taiwan”. *African Journal of Business Management*, 5.

[11] Wu, ChaoYen & Ku, ManTing & Chan, HsinTe & Mai, YuanChen. (2012). “An empirical study of US stock market influence to Taiwan stock market - Using the S&P500 and TWSE”. *International Journal on Advances in Information Sciences and Service Sciences*. 4. 346-355. 10.4156/aiss.vol4.issue13.43.

[12] Ping Zhang & Jieying Gao, Yanbin Zhang & Te-Wei Wang. (2021). "Dynamic Spillover Effects between the US Stock Volatility and China’s Stock Market Crash Risk: A TVP-

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

VAR Approach". *Mathematical Problems in Engineering*, vol. 2021, Article ID 6616577, 12 pages, 2021. https://doi.org/10.1155/2021/6616577

[13] Xiong, Z., Han, L. "Volatility spillover effect between financial markets: evidence since the reform of the RMB exchange rate mechanism". *Financial Innovation* 1, 9 (2015). https://doi.org/10.1186/s40854-015-0009-2

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)