The Validity of Applying State Space Model to Japanese Stock Market

International Journal of Economics and Financial Modelling
Vol. 3, No. 1, 1-8, 2018

Yutaka Kurihara[1]
Shinichiro Maeda[2]

[1]*Aichi University, Japan*
Email: kurihara@vega.aichi-u.ac.jp Tel: +81-52-564-6111
[2]*Kyushu University, Japan*
Email: smaeda@econ.kyushu-u.ac.jp Tel: +81-92-642-2476

(Corresponding Author)

ABSTRACT

This paper examines recent Japanese stock prices using the state space model. Time series analyses like the GARCH model have often been used for estimation or prediction, but state space analyses have not been used as often. Whether or not the validity of applying the state space model to the Japanese stock market is appropriate is examined in this study. Japan was in recession for over twenty years, and a large financial crisis hit all over the world including Japan in 2008. After that, Abenomics, a huge monetary expansion from 2013, has been conducted in Japan. This paper examines the two periods from 2008–2012 and from 2013–2017 and employs the state space model to examine the Japanese stock prices. The empirical results show that the state space model fits well to examine Japanese stock prices and components of trend is larger during the period of Abenomics. From the conduction of Abenomics, stock price has mainly been moving according to the movement of the trend.

Keywords: *Abenomics, Japanese stock price, State space model.*
JEL Classification: *E52; G12; G17.*
DOI: 10.20448/811.3.1.1.8
Citation | Yutaka Kurihara (2018). The Validity of Applying State Space Model to Japanese Stock Market. International Journal of Economics and Financial Modelling, 3(1): 1-8.

Funding: This study is supported by JSPS KAKENHI.
Competing Interests: The authors declare that they have no competing interests.
History: Received: 9 March 2018/ Revised: 2 April 2018/ Accepted: 4 April 2018/ Published: 6 April 2018
Publisher: Online Science Publishing

1. INTRODUCTION

Stock prices have been empirically examined in many ways from the past. After time series analyses had improved along with the theoretical analyses, AR, MA, ARMA, and ARIMA have been used. Recently, GARCH models, which take many forms of methods, are being used for estimation as explained below. GARCH is now used in many kinds of financial asset prices such as stock, bond, currency (exchange rate), derivatives, or gold and commodities, and some newcomers, for example, Bitcoin (Kurihara and Fukushima, 2018). On the other hand, the birth of the state space model is not so new, however, this model has not been used for stock price estimation and prediction.

A state space model can be described as a probabilistic graphical model. More concretely, it denotes the probabilistic dependence between the latent state variable and the observed one. The state or the observed can be either continuous or discrete. The model is said to be born in the 1960s in the area of control engineering field, which provides a general framework for analyzing stochastic and deterministic dynamical systems that are observed or measured through a stochastic process. The state space model has been repeatedly and successfully applied in engineering and computer science as well as in statistics and economics to solve a broad range of dynamic framework problems. Other terms used to describe state space models are included in Markov models and other process models. Recently, the Kalman filter that denotes an algorithm for inferring linear Gaussian frameworks has been used in the state space model.

Among time series analyses, stock prices have been started to be examined using AR, MA, ARMA, and ARIMA. Recently, GARCH models have been employed, and some developed GARCH models are used for estimation. Component GARCH (CGARCH) uses the variables in the transitory estimation. They have an impact on the short-term movements in volatility while the variables in the permanent equation impact the long-term levels of volatility. Power GARCH (PGARCH) uses a power parameter. The power parameter, which uses the standard deviation, is estimated rather than imposed. In exponential GARCH (EGARCH), the leverage effect is exponential rather than quadratic, and the forecasts of the conditional variances are guaranteed to be nonnegative.

For stock market analyses, some kinds of GARCH models have been used for many countries, many kinds of stock prices, and different sample periods. Moon and Yu (2010) indicated that the GARCH (1,1)-M model has evidence of a symmetric and asymmetric volatility spillover from the United States to China's stock market, significantly. Asharian *et al.* (2013) revealed that including low-frequency macroeconomic variable by using the GARCH-MIDAS model outperforms the prediction. It also finds one interesting point that prediction accuracy is linked with the long-term variances. Ulici *et al.* (2014) showed the relationship between shock price and stock return volatility for the cases of Romanian banks. Sharma (2015) found that the standard GARCH model fits netter than advanced GARCH models in 21 countries' stock price indexes across the world. Al-Najjar (2016) provided evidence that ARCH/GARCH models can provide reasonable characteristics of stock market returns in Amman stock exchange market. Kambourroundis *et al.* (2016) showed that implied volatility of stock prices shows a predictable pattern and reveals the existence of a relationship between implied volatility in stock returns and the index returns significantly. Molner (2016) showed that a range-GARCH (1,1) model fits better than the standard GARCH model when analyzing stock price returns. Reher and Wilfling (2016) indicated significant evidence of Markov-switching structures in German stock markets. Tripathy (2017) revealed the significant presence of asymmetric and leverage effects in all BRIC countries' stock market returns using GARCH, CHARMA, APARCH, and CGARCH models. Valera *et al.* (2017) provided evidence that there is a relationship between stock market uncertainty and interest rate volatility significantly. There are a lot of studies that analyze stock prices using GARCH models.

Compared with these analyses using GARCH models, there are not so many studies in examining stock prices by using the state space model in spite of its availability and expediency. This situation is not limited to other financial asset prices such as exchange rates and interest rates. Among these financial asset prices, there are some studies that examine stock prices using state space models. However, the number of these studies is not large. Zhou and Qing (2000) indicated that a parsimonious state space model captures the variation in expected stock returns at any horizon, the extracted expected returns explain a substantial proportion of the variance in its realized returns, and the maginitude of this proportion increases according to the horizon of stock returns. Choi and Park (2013) applied the state space model to the Korean stock market and found that expected stock returns significantly change over time and have persistent and predictable elements. Ng *et al.* (2013) also applied non-Gaussian and non-linear state space models to the S&P500 stock index. Koopman *et al.* (2015) proposed a general likelihood evaluation method of nonlinear non-Gaussian state-space models by using the simulation method of efficient sampling method and showed efficient gains for U.S. stock price returns with multiple volatility elements. Christian and Yang (2016) employed panel data with the state space model and found that Apple stock return can be applicable to this model. De Moura *et al.* (2016) proposed a pairs-trading strategy, which is based on linear state space models made for modelling the spread formed with a pair of assets and find the model outperforms some kinds of market benchmarks. De Souza *et al.* (2013) applied the state space model to exchange rates and found that the variance of the exchange rate pass-through, the monetary policy and the international trade flow have shown to be significant determinants of the exchange rate pass-through.

In Japan, prolonged recession has been ongoing, but some bright signs have been appearing. Recent drastic monetary policy that expands monetary base is said to influence Japanese stock prices positively. In reality, stock prices have been increasing since the drastic monetary policy from the year of 2013. Whether or not the validity of applying the state space model to recent stock prices in Japan is applicable is empirically examined in this study.

Following section 1, section 2 provides the space state model and reveals a model used in this study. Section 3 reviews the recent Japanese economy. From the view of stock price movements, this paper's sample period is divided into two parts. The reason is explained in this section. In section 4, empirical analyses employing state space model is conducted based on the model explained in section 2. The results are provided in this section. The empirical results are analyzed in section 5. Finally, this paper ends with a brief summary.

2. STATE SPACE MODEL AND ITS APPLICATION TO JAPANESE STOCK PRICE

This study is to examine the validity of empirically applying the state space model to Japanese stock prices. The model used in this paper is a typical one. A common state space model takes this form:

$$\mathrm{X}t+1 = AXt + ut \qquad (1)$$

$$\mathrm{Y}t = CXt+jt \qquad (2)$$

where the vector X is the state vector and t denotes time. Equation (1) is how this vector X, which is a constant, appears to be only tenuously connected with the data. Yt evolves with time. In the equation (1) and (2), ut and jt denote exogenous disturbances which are included in the state transition. Observation equations are positively, mutually correlated, but they are serially uncorrelated.

In this study, the basic concept is the same with the equations (1) and (2). Following equations (1) and (2), in this paper, these models (3), (4), (5), (6), and (7) are hypothesized;

$$STOCKt = Tt + Ct + et \qquad (3)$$

$$Tt = 2Tt\text{-}1 - Tt\text{-}2 + v1t \qquad (4)$$

$$Ct = \phi 1Ct\text{-}1 + \phi 2Ct\text{-}2 + v2t \qquad (5)$$

$$Tt\text{-}2=Tt\text{-}1 \quad (6)$$

$$Ct\text{-}2=Ct\text{-}1 \quad (7)$$

Equation (3) is an observation equation. STOCK is the stock price and is a real value. T and C are unobserved variables, and they are trend (T) term and cycle (C) term. Only STOCK is the observation value. In equation (4), trend (T) is hypothesized as a quadratic function often employed in the state space model. Equation (5), which denotes the cyclicity, is supposed to be AR(2). The Autoregressive model denotes that it is a regression of the variable against itself. Finally, et and vt are assumed to be white noise. The daily date (at the end of the market opening day) is used for estimations.

3. RECENT JAPANESE ECONOMIC CONDITION

In the previous two sections, the state space model employed in this study was explained and the previous studies and related studies such as GARCH model as time series analyses were reviewed. In this section, the recent Japanese economic condition is explained. The sample period in this study is ten years. From the view of stock price movements, this paper's sample period is divided into two. The reason why it can be split into two periods is also explained in this section (see, for example, Kurihara (2015)).

Japan enjoyed stable and high economic growth in the 1980s, and stock and land prices spurred greatly. The economic condition was said to be a *bubble* economy. The Japanese currency, yen, appreciated largely; however, exports strongly related to and important factors to the Japanese economic growth did not damage. Luckily, the inflation rate did not rise strongly, so household consumption was not damaged. Companies could obtain a lot of gains from this situation. Some companies invested a lot of money to businesses not to their core related businesses. However, the so-called *bubble* economy, in which stock and land prices rose, collapsed suddenly at the beginning of the 1990s, and the Japanese economy has experienced serious economic conditions since. The situation continued to deteriorate the Japanese economy. In the 1990s, Japan suffered another serious recession. The reason that the recession occurred is said to be the fragile Japanese financial system and structural problems, such as delays in political and economic systems and reforms and deregulation in many areas. Companies did not have strong international competitiveness by that time. The Japanese central bank, the Bank of Japan (BOJ), conducted a new financial policy, the quantitative easing policy, in March 2001. It was said that the policy is the first of its kind conducted in the world. It was, at least, an unprecedented policy. However, the BOJ quit quantitative easing in March 2006, as there were some bright signs could be seen.

Around 2008, a global financial crisis occurred. It caused a serious economic condition in Japan, too. The Japanese economy was seriously influenced by many other countries including the United States. The BOJ increased the purchases of Japanese government bonds aggressively to flow capital into the financial markets. Declines in stock prices and yen appreciation occurred at the same time, and the Japanese economy was injured as a result. Under such serious conditions, the Japanese government changed to a new and drastic policy, called *Abenomics*. Abe was and is now the name of Japan's new prime minister at that time. Abenomics is distinguished by a set of policies that is made of three branches: (1) aggressive monetary policy, (2) fiscal consolidation, and (3) growth strategy. In 2013, the BOJ and the Japanese government decided to cooperate with each other to combat the serious economic condition and published a joint statement. At that time, under huge debt, the government demanded a more aggressive financial policy. The BOJ started to conduct monetary policy based on the principle that the policy shall be aimed at achieving price stability (combating deflation in reality), thereby contributing to the sound growth of the Japanese economy. The government would revitalize Japan's economy by conducting flexible management of macroeconomic policy and by conducting measures to strengthen the competitiveness and growth potential of the

Japanese economy. In addition, by strengthening coordination between the government and the BOJ, the government would steadily promote measures aimed at the establishment of a sustainable fiscal structure to ensure the credibility of fiscal management. Japanese fiscal expansion again started to increase. Also, Abe recently announced a nominal GDP target of \600trn (from around \500trn now) by promoting Abenomics.

This paper focuses on the years of 2008 and 2013. In 2008, a worldwide financial crisis occurred, and it hit the Japanese economy. In 2013, Abenomics started and rising stock prices, the depreciation of the yen, and lower interest rates widely occurred.

4. EMPIRICAL RESULTS

The model employed here was explained in section 2. Also, the sample period was explained in the previous section. The empirical results are from Table 1 to Table 4.

Table-1. Full sample period

	coefficient	**Std.error**	**z-statistic**	**Pob.**
C(1)	-0.5827	1.86E-06	-313497.2	0.0000
C(2)	-0.4721	1.67E-06	-282276.6	0.0000
	Final state	Root Mean Squared Error	z-statistic	Prob
SV1(trend)	22916.47	1.8510	12380.40	0.0000
SV2(trend)	22914.58	0.8123	28207.79	0.0000
Sv3(cyclicity)	11.39913	1.1544	9.8740	0.0000
Sv4(cyclicity)	-3.3657	0.8123	-4.1432	0.0000
Log likelihood	-12824575	Akaike info criterion		10473.32
Parameters	2	Schwartz criterion		10473.32
Diffuse priors	4	Hannan-Quinn criterion		10473.32

Note: SV denotes stable variance. Initial values of SV3=0 and initial values of variances of error terms of SV1=SV3=1.

Table-2. First part of the sample period (from 2008 to 2012)

	coefficient	**Std.error**	**z-statistic**	**Pob.**
C(1)	-0.5567	2.94E-06	-189274.9	0.0000
C(2)	-0.4886	2.53E-06	-192899.4	0.0000
	Final state	Root Mean Squared Error	z-statistic	Prob
SV1(trend)	14540.93	1.8552	5635.465	0.0000
SV2(trend)	10321.71	0.8166	12639.15	0.0000
Sv3(cyclicity)	-21.1622	1.1494	-18.4109	0.0000
Sv4(cyclicity)	1.2691	0.8166	1.5541	0.1202
Log likelihood	-4914296	Akaike info criterion		8023.344
Parameters	2	Schwartz criterion		8023.352
Diffuse priors	4	Hannan-Quinn criterion		8023.347

Note: SV denotes stable variance. Initial values of SV3=0 and initial values of variances of error terms of SV1=SV3=1.

Table-3. Second part of the sample period (from 2013 to 2017)

	coefficient	**Std.error**	**z-statistic**	**Pob.**
C(1)	-0.5986	2.41E-06	-247890.8	0.0000
C(2)	-0.4610	2.25E-06	-205094.2	0.0000
	Final state	Root Mean Squared Error	z-statistic	Prob
SV1(trend)	22915.54	1.8483	12397.51	0.0000
SV2(trend)	22914.11	0.8096	28299.63	0.0000
Sv3(cyclicity)	10.95138	1.1576	9.4615	0.0000
Sv4(cyclicity)	-2.8987	0.6096	-3.5800	0.0003
Log likelihood	-7892831	Akaike info criterion		12907.33
Parameters	2	Schwartz criterion		12907.34
Diffuse priors	4	Hannan-Quinn criterion		12907.33

Note: SV denotes stable variance. Initial values of SV3=0 and initial values of variances of error terms of SV1=SV3=1.

Table-4. Component analysis

	Full sample period		First part of the sample		Second part of the sample	
	Trend	Cyclical	Trend	Cyclical	Trend	Cyclical
Average	3.10	2.62E-05	153.67	-159.33	6.7535E-05	-3E-05
STDEV.	12668.12	14078.45	11576.14	13381.6	13715.80	14732.96

The detailed discussion is performed, but the results are almost robust. The state space model fits well with the Japanese stock price. Moreover, there seems to be a strong difference between the two sample periods.

5. ANALYSES OF THE EMPIRICAL RESULTS

As confirmed in the previous section, the state space model fits well for both periods. The difference is that there is a large difference in the trend. Compared to the first period (from 2008 to 2012), the trend is quite large in the second period (from 2013 to 2017). On the other hand, the cyclical parts are difficult to understand, but all of them are significant. It is certain that there are cyclical parts along with the trend parts in the time series.

Why does the trend component exist? Figure 1 would help us to understand the results. The up and down trend seems clearer during the first period than the second period. In Abenomics, it has been said that monetary expansion has led to stock price rising, so there would be a stable trend in stock prices.

Figure-1. Japanese Stock Price

Source:: Nikkei Telecom

6. CONCLUSION

This paper examined recent Japanese stock prices using the state space model. State space analyses for analyzing Japanese stock prices are useful, but the model has not been used often in analyzing stock prices. Whether or not the validity of applying the state space model to the Japanese stock market is appropriate was examined in this study, and, as a result, it fit quite well. From 2013, Abenomics, a huge monetary expansion, has been conducted in Japan. This paper examined the two periods from 2008 to 2012 and from 2013 to 2017 and found that the components of trend is larger during the period of Abenomics from 2013. From the conduction of Abenomics, stock prices have mainly been moving according to the movement of the trend.

There is some room for analyses. One is that the results are not the evaluation of Abenomics. Many researchers think that there is a relationship between monetary expansion and stock prices, but there is a huge discussion whether or not this policy has been appropriate. Exit strategy from the unprecedented policy is and will be discussed, and there would be some possibility to have side effects on the economy. Achievement of combating deflation, which is the main target of this policy, could have been succeeded or not cannot be evaluated easily and have not reached a consensus by now. Also, there would be some possibility that exchange rates should be taken into account. The Japanese economy seems to be influenced by exchange rates., and further study is necessary to analyze stock prices and financial asset prices.

REFERENCES

Al-Najjar, D., 2016. Modelling and estimation of volatility using ARCH/GARCH models in Jordan's stock market. Asian Journal of Finance and Accounting, 8(1): 152-167. *View at Google Scholar* | *View at Publisher*

Asharian, H., A. Hou and F. Javed, 2013. The importance of the macroeconomic variables in forecasting stock return variance: A GARCH-MIDAS approach. Journal of Forecasting, 32(7): 600-612. *View at Google Scholar* | *View at Publisher*

Choi, K.H. and C. Park, 2013. State-space model and present value model: An application to the Korean stock market. Journal of Economics, Theory, and Econometrics, 24(1): 1-15. *View at Google Scholar*

Christian, G. and L. Yang, 2016. A flexible state-space model with application to stochastic volatility. Centre de Recherche en Economie et Statistique, Working Papers No. 2016-2039.

De Moura, C.E., A. Pizzinga and J. Zubell, 2016. A pairs trading strategy based on linear state space models and the Kalman filter. Quantitative Finance, 16(10): 1559-1573. *View at Google Scholar* | *View at Publisher*

De Souza, R.M., L.F.P. Maciel and A. Pizzinga, 2013. State space models for the exchange rate pass-through: Determinants and null/full pass-through hypotheses. Applied Economics, 45(36): 5062-5075. *View at Google Scholar* | *View at Publisher*

Kambourroundis, D.S., D.G. McMillan and K. Tsakou, 2016. Forecasting stock return volatility: A comparison of GARCH, implied volatility, and realized volatility models. Journal of Future markets, 36(12): 1127-1163. *View at Google Scholar* | *View at Publisher*

Koopman, S.J., A. Lucas and M. Scharth, 2015. Numerically accelerated importance sampling for nonlinear non-gaussian state-space models. Journal of Business & Economic Statistics, 33(1): 114-127. *View at Google Scholar* | *View at Publisher*

Kurihara, Y., 2015. Asset price and monetary policy: The Japanese case. Journal of Applied Finance & Banking, 5(4): 1-9. *View at Google Scholar*

Kurihara, Y. and A. Fukushima, 2018. How does price of bitcoin volatility change? International Research in Economics and Finance, 2(1): 8-14. *View at Google Scholar* | *View at Publisher*

Molner, P., 2016. High-low range in GARCH models of stock return volatility. Applied Economics, 48(51): 4977-4991. *View at Google Scholar* | *View at Publisher*

Moon, G.H. and W.C. Yu, 2010. Volatility spillovers between the US and China stock markets: Structural break test with symmetric and asymmetric GARCH approaches. Global Economic Review, 39(2): 129-149. *View at Google Scholar* | *View at Publisher*

Ng, J., N.J. Forbes, G.M. Martin and B.P.M. McCabe, 2013. Non-parametric estimation of forecast distributions in non-gaussian, non-linear state space models. International Journal of Forecasting, 29(3): 411-430. *View at Google Scholar* | *View at Publisher*

Reher, G. and B. Wilfling, 2016. A nesting framework for Markov-Switching GARCH modelling with an application to the German stock market. Quantitative Finance, 16(3): 411-426. *View at Google Scholar* | *View at Publisher*

Sharma, P., 2015. Forecasting stock index volatility with GARCH models: International evidence. Studies in Economics and Finance, 32(4): 445-463. *View at Google Scholar* | *View at Publisher*

Tripathy, N., 2017. Do BRIC countries stock market volatility move together? An empirical analysis of using multivariate GARCH models. International Journal of Business and Emerging Markets, 9(3): 104-123. *View at Google Scholar* | *View at Publisher*

Ulici, M., A. Chaibi and C. Rault, 2014. Shock and volatility transmissions between bank stock returns in Romania: Evidence from a VAR-GARCH approach. Journal of Applied Business Research, 30(3): 689-699. *View at Google Scholar* | *View at Publisher*

Valera, H.G., M.J. Holmes and G. Hassan, 2017. Stock market uncertainty and interest rate behavior: A panel GARCH approach. Applied Economics Letters, 24(11): 732-735. *View at Google Scholar* | *View at Publisher*

Zhou, C. and C. Qing, 2000. A state-space model of short-and long-horizon stock returns. Journal of Financial Research, 23(4): 523-544. *View at Google Scholar* | *View at Publisher*