Commodity Price Effect on Stock Market: A Markov Switching Vector Autoregressive Approach

[1]Phoong Seuk Wai, [2]Mohd Tahir Ismail, and [3]Sek Siok Kun

[1,2,3]Universiti Sains Malaysia
School of Mathematical Sciences
11800 Minden, Penang, Malaysia
1wai_phoong@yahoo.com, 2mtahir@cs.usm.my, [3]sksek@usm.my

Abstract— Real economic data always present nonlinear properties such as asymmetry and radically change in the series through time. Missing data and jumps as well as breaks also common reported in economic time series model. Thus, linear models are no longer suitable used in estimate the economic data and markov switching vector autoregressive model (MS-VAR) is applied in study the economic model. This paper will present the analysis of commodity price effect on stock market by using markov switching vector autoregressive model. Oil price and gold price are selected to represent the commodity price and the influence of those prices on Malaysia, Singapore, Thailand and Indonesia stock market are investigated. Furthermore, the mean adjusted markov switching vector autoregressive model (MSM-VAR) and mean adjusted heteroskedasticity markov switching vector autoregressive model (MSMH-VAR) are investigated to determine the suitable specification of the model in providing a more significance and reliable result when analysis the economic relationship model between oil price, gold price and stock market returns.

Index Terms— Markov Switching Vector Autoregressive Model, Mean Adjusted, Heteroskedasticity, Stock Market and Commodity Price

I. INTRODUCTION

Nonlinear time series models became popular through the past two decades in economic and financial field. Fan and Yao (2003) [1] define that nonlinear time series is not a linear stochastic process but is generated by nonlinear dynamic properties such as time varying, higher-moment structures, asymmetric cycles, and jumps or breaks exist in the time series sequence. Markov switching autoregressive model is one of the popular nonlinear time series model and proposed by Hamilton (1989) [2]. The Hamilton model is then extended to Markov switching vector autoregressive model (MS-VAR) by Krolzig.

According to Krolzig (1997) [3], MS-VAR model have become increasingly prominent in applications since it is able to detect the classical business cycle phases and detect the difference in terms of average growth rates of the economy. Moreover, MS-VAR model also can increase the reliability of analysis of the business cycle, and provide useful information in the study of economic relationship because of its properties on detection the high level regime. Therefore, the perception of the current state of economy can be improving.

In addition, MS-VAR model are a nonlinear model which commonly applied in economic and financial time series to analysis and predict the economy and financial relationship, and give implication on the economic theories since MS-VAR model able to estimate the dramatically changes or breaks that happened in the data through time such as at the last decade oil price shocks, structural change or break in the stock market prices are happen because of the events like Asian Financial Crisis and '9-11'. Commodity prices such as gold and oil always relate to the movement of the stock market prices. Historical evidence was shown that when the global economy was in the recession period, the demand of oil and gold will be increased. . Although oil and gold are limited reservation but oil belongs to a basic of energy sources which affect the country's economy as states by Sauter and Awerbuch (2003) [4] and gold is a popular investment. Both of these two commodity prices implies on the country's GDP especially in stock market index.

In this study, MS-VAR model is choose to use in analysis the implication of the world oil price (OP) and gold price(GP) in Malaysia stock market return (KLCI), Singapore stock market return (STI), Thailand stock market return (SETI) and Indonesia stock market return (JCI) since commodities are the primary inputs to many manufactured things and services.

Oil price is an important commodity that able to directly influence the world market especially in stock market are included in this study since Bhar and Hammoudeh (2011) [5] describe that oil price is positively leads the stock market in a normal state. Besides that, gold which is a popular investment of the investors also will be take account in the study. This is because there are investors believe that gold is a liquid assets which can be use to buy a low-value stock or pay other assets and gold also believe that has less investment risk compare to the others commodity. Thus commodity prices pay role in affecting the

general price level in a country. While "Trading on the stock market is set to be brisk as bulls attempt to break out from bear territory" which reported in New Straits Times on 21st March 2011 show that stock market pay an important role in the country economy and as an indicator to reflect any changes in the country economy. So, the relationship between OP, GP and stock market index are examined in this study.

The structural of this paper is as follows. The section 2 discusses the methodology of the study. Section 3 presents the results and discussion. Lastly, section 4 presents the conclusion of this study.

II. METHODOLOGY

Stationary test is used to detect whether the time series data have a constant mean, variance or auto-covariance since in real world data, extreme changes always exist in economic model. Many economic data exhibit non-stationary behavior such as regime switching and jumps therefore Augmented Dickey-Fuller (ADF) test and Kwiatkowski-Philips-Schmidt-Shin (KPSS) test are important to apply in the study to check the occurrence of the random walk or unit root problem in the time series data.

Next is cointegration test where Johansen test is used to examine the properties of the series (check the existence of the stationary linear combination). Furthermore, the presence of cointegration in the series must take account the method to test the occurrence of the unit roots in the variables.

Although Ordinary least square regressions can given an accurate result in large samples, but this test is not used in estimate the non-stationary variables since cointegration test is a powerful tool in estimate the existence of the unit root in nonlinear time series data and has strength when the time series data have a limited length. Therefore, if the variables in the set are not cointegrated, then MS-VAR model will applied in study the economic relationship model since MS-VAR class of models provides a convenient framework to analysis multivariate changes in regimes.

The general idea of the MS-VAR model is the n-dimensional vector time series vectors, $y_t = (y_{1t}, ..., y_{nt})$ depend upon an unobserved regime variable, $s_t \in \{1, ..., n\}$ which represents the probability of being in a particular state to the switching mechanism in various states. The conditional probability density of the observed yt is given by

$$P(y_t | Y_{t-1}, s_t) = \begin{cases} h(y_t | Y_{t-1}, \beta_1) \text{ if } s_t = 1 \\ \vdots \\ h(y_t | Y_{t-1}, \beta_n) \text{ if } s_t = n \end{cases}$$

Where β_n is the VAR parameter vector with regime n and Yt-1 is the past information. Thus, the parameter vector, β depend on the regime at time t.

If the mean vector $\mu(s_t)$, vector of autoregressive process $A(s_t)$ and matrix of variance-covariance $\sum(s_t)$ are subject to shift in regime; thus, the general form of the equation MS-VAR will be

$$Y_t = \mu(s_t) + \sum_{m=1}^{r} A_m (Y_{t-m} - \mu_{t-m}) + \varepsilon_t \qquad (1)$$

$$\varepsilon_t \sim \text{i.i.d } N(0, \textstyle\sum_{s_t})$$

While the mean adjusted MS(2)-VAR(p) model can be generalize as

$$y_t - \mu(s_t) = A_1(s_t)(y_{t-1} - \mu(s_{t-1})) + A_2(s_t)(y_{t-2} - \mu(s_{t-2})) + u_t \qquad (2)$$

Where $u_t \sim \text{NID}(0, \sum(s_t))$ and $\mu(s_t), A_1(s_t), ..., A_2(s_t), \sum(s_t)$ are parameter shift functions.

III. RESULTS AND DISCUSSION

ADF test and KPSS are as the first step in the testing procedure in this study because want to check the stationarity of the series. The following graph presented all the behavior of the variables before undergoing the tests.

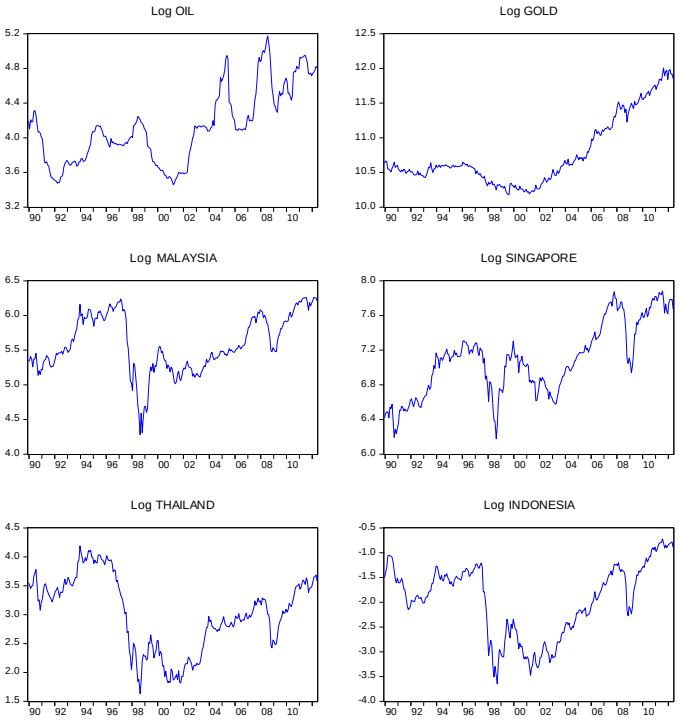


Fig. 1. Time series properties of the variables

Results from ADF and KPSS show that all the variables in the model including OP, GP, KLCI, STI, SETI and JCI are non-stationary and able to transform into stationary series after taking first differencing process.

Next, Johansen Cointegration Test is used to test the cointegrated relations between the series since all the series has the same integration order. There are two types Johansen Cointegration Test that are Johansen Trace Test and Johansen Maximum Eigenvalue Test. According to Johansen (1991) [6], these two tests have different hypothesis where the hypothesis of the trace statistic test in this study are

H_0: There is at most r cointegrating relations

H_1: There are m cointegrating relations

While the hypothesis of maximum eigenvalue statistic test in this study are

H_0: There is at most r cointegrating relations

H_1: There are $r + 1$ cointegrating relations

Where cointegration order, r = 0, 1, 2, 3, 4 and m is the total of cointegrating relations that may exist in the test. Before start analysis the cointegration relations between the variables, number of lags need to be determine first because it may affect the accuracy of the results. Therefore, VAR model of estimating the endogenous variables in the model are carry out to determine the lag order of the cointegration test. Lag order is important since higher lag will results lost many data thus VAR Lag Order Selection Criterion is test before investigate the existence of the cointegrated relations between the variables and the outputs are summarizes and grouped in the tables below:

TABLE I
Johansen Cointegration Test of OP, GP, KLCI, STI, SETI and JCI

Johansen Cointegration Test				
Hypothesis on no. of CE	Trace Test		Maximum-Eigen test	
	0.05 Critical value	Trace statistic	0.05 Critical value	Maximum-Eigen statistic
None	83.93712	89.7910* (0.0176)	36.63019	30.0542 (0.2389)
At most 1	60.06141	59.7368 (0.0532)	30.43961	23.7657 (0.2688)
At most 2	40.17493	35.9711 (0.1244)	24.15921	18.7642 (0.2274)
At most 3	24.27596	17.2070 (0.2982)	17.79730	12.8326 (0.2388)
At most 4	12.32090	4.3743 (0.6568)	11.22480	3.0957 (0.7729)
At most 5	4.129906	1.2786 (0.3015)	4.129906	1.2786 (0.3015)

The value in () is represent to the p-value
* denotes rejection of the hypothesis at the 0.05 level

Lag order 2 is choose for estimate the time series model because of the suggestion result from Final Prediction Error and Akaike Information Criterion (AIC). At most five cointegrating equations may exist in the model since six variables are tested that are OP, GP, KLCI, STI, SETI and JCI. Results show that, there are no cointegrating relations exist between the parameters. So, MS-VAR is used in estimate the economic relationship of the model.

MSM(M)-VAR(p) model and MSMH(M)-VAR(p) model are build up to estimate the economic relationship between the variables but MSMA(M)-VAR(p) model and MSMAH(M)-VAR(p) model are not implement in analysis the economic relationship model since the autoregressive parameter in the economic model is not vary. The purpose to choose mean as a varying factor when build up the model is because it is probable to assume that mean able be adjusted to a new level after a translation from one state to another state or also means that a permanent regime switching in mean $\mu(st)$ can cause an immediate jump of the observed time series vector to a new level.

TABLE II
MS(2)-VAR(1) models for OP, GP, KLCI, STI, SETI and JCI

	MSM(2)-VAR(1)					
	OP	GP	KLCI	STI	SETI	JCI
μ_1	-0.014	-0.030	-0.196	-0.152	-0.203	-0.336
μ_2	0.003	0.006	0.010	0.010	0.007	0.013
σ	0.062	0.043	0.076	0.072	0.097	0.096
Matrix Of Transition Probabilities, p_{ij}						

	$s_{t-1} = 1$	$s_{t-1} = 2$
$s_t = 1$	0.6167	0.3833
$s_t = 2$	0.0121	0.9879
Regime Properties		
	No. of Observations	Probability	Duration
$s_t = 1$	9.1	0.0306	2.61
$s_t = 2$	258.9	0.9694	82.74

LR = Likelihood Ratio linearity test
The values in ( ) is represent to the t-values
** indicates that the p-value is significant at 5% level

	MSMH(2)-VAR(1)					
	OP	GP	KLCI	STI	SETI	JCI
μ_1	0.008	0.002	-0.007	-0.005	-0.008	-0.017
μ_2	0.003	0.006	0.010	0.011	0.007	0.013
σ_1	0.097	0.058	0.132	0.122	0.150	0.174
σ_2	0.039	0.035	0.047	0.045	0.075	0.067
Matrix Of Transition Probabilities, p_{ij}						
	$s_{t-1} = 1$	$s_{t-1} = 2$				
$s_t = 1$	0.7230	0.2770				
$s_t = 2$	0.1185	0.8815				
Regime Properties						
	No. of Observations	Probability	Duration			
$s_t = 1$	81.400	0.299700	3.61000			
$s_t = 2$	186.600	0.700300	8.44000			

LR = Likelihood Ratio linearity test
The values in ( ) is represent to the t-values
** indicates that the p-value is significant at 5% level

The role of OP, GP, KLCI, STI, SETI and JCI are assessed with the MS(2)-VAR(1) model to estimate the relationship of the economic model. First regime is represent to the recession state and second regime is the growth state since regime 1 coefficients is smaller than regime 2. In economy, recession state also known as "Bear" market and growth state also known as "Bull" market.

MSM(2)-VAR(1) model is a mean adjusted model after a switch in regime with variant mean. All coefficients of the lag component in first regime in MSM-VAR model are negative. This shows that a decreasing of monthly return is happened on oil price with average 1.4% and in gold price with average 3%. While the second regime which represent the "Bull" market reported an increasing of average 0.3% in oil price and 0.6% in gold price are positively increasing in average of the KLCI, STI, SETI and JCI monthly index. Among these four selected South East countries; JCI market reported the largest increasing and decreasing country in the monthly return either in "Bull" market or in "Bear" market.

The transition probability p11 = 0.61167 and p22 = 0.7879 suggest that the second regime is the persistence state since the transition probability of the growth regime is higher than the recession regime. Furthermore, the computed transition probability, $\text{Prob}(s_t = 1 | s_{t-1} = 2) = 0.3833$ reported that an increasing transition probability occurs from a crisis regime (regime 1) to the growth regime (regime 2).

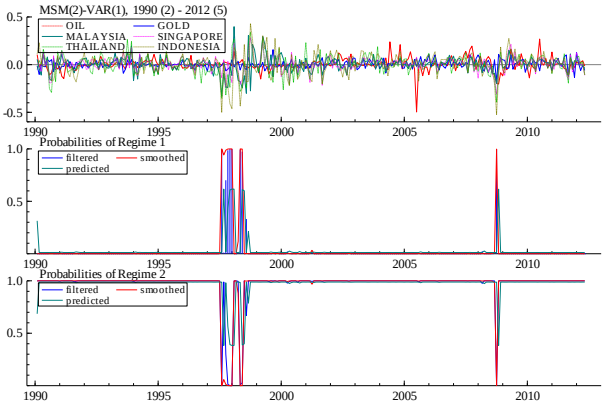
Number of observations that including in the growth state is 259 which is 96.94% of the total sample size and the average duration of each regime are 2.61% on regime 1 and 82.74% on regime 2. This denotes that regime 2 is the dominant phases in the economic model and asymmetric property is present. Crisis economy 1997 may act as a significant issue that indicates a shift of the series of OP, GP, KLCI, STI, SETI and JCI from first regime to second regime.

Besides that, MSMH(2)-VAR(1) model which estimate vary mean and variance of the variables has the same representation state that the first regime (st = 1) is the "Bear" market and second regime (st = 2) is the "Bull" market. When comparing the MSM-VAR model and MSMH-VAR model, OP and GP have different sign in first regime (recession state). In MSMH-VAR model, OP recorded a high volatility of 0.94% and a high positive average monthly probability of 0.8% in regime 2 compare to 0.16% of volatility and 0.003 or 0.3% of average monthly return in MSM-VAR model.

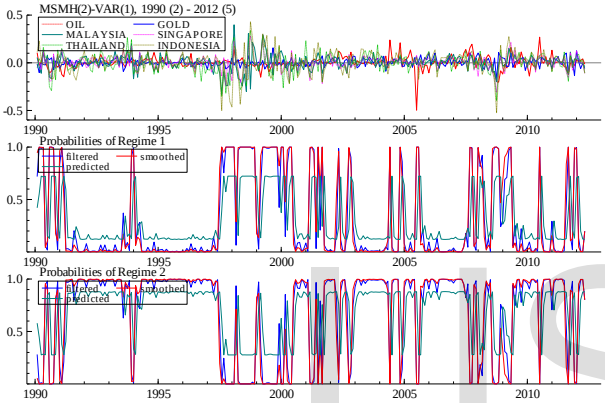
While gold price recorded 0.2% average of monthly price and $\sigma 2(st = 1) = (0.058)2 = 0.00336 = 0.34\%$ of monthly volatility in regime 1 and a high positive average of monthly price with small volatility value in regime 2.

The transition probability of state 1 is $\text{Prob}(s_t = 1 | s_{t-1} = 1) = 0.7230$ and $\text{Prob}(s_t = 1 | s_{t-1} = 2) = 0.8815$ describes that regime 2 has the higher probability than regime 1. A higher probability of transition from recession state to growth state also reported in the MSMH-VAR models and the duration of these two regimes also show same conclusion with MSM-VAR model that a significant asymmetries is presence in the business cycle. While the transition probabilities can be write in a matrix form,

$$P = \begin{bmatrix} 0.7230 & 0.2770 \\ 0.1185 & 0.8815 \end{bmatrix}$$



MSM(2)-VAR(1)



MSMH(2)-VAR(1)

Fig. 2. MS-VAR Probabilities

Graph 2 show two type of specifications regime properties in mean adjusted after a changes in regime and each MS-VAR model including three panels that are: first panel present how the inferred regime probabilities are translated into switching in the mean growth rate of the variables, second panel show the filtered and smoothed probabilities of regime 1 and third panel reported the filtered and smoothed probabilities of regime 2.

Smoothed probability is the optimal inference of the turning points on the regime at time t which estimate the business cycle by using the whole sample information, $\Pr(s_t = j|Y_T)$. While filtered probability is the optimal inference on the state variables at time t by using the information at time t only, $\Pr(s_t = j|Y_t)$ and this two probability are sketch to explain the economic model of the variables OP, GO, KLCI, STI, SETI and JCI.

Regime 1 of each model depicts very precisely the recession of the year 1998 and 2009 in MSM-VAR model. However, smoothed probabilities of MSMH-VAR model indicate a long recession from end of the year 1997 until the year 2000, and a few short recession period such as at 1990, 1994, middle year of 2001 and 2008. While regime 2 is represent to the growth period in the business cycle.

Furthermore, MSM-VAR and MSMH-VAR model display that the smoothed probabilities of all models show that the downswings are sudden and much shorter but the upswings are more gradual and highly persistent.

When comparing the log-likelihood, AIC, HQ and SC among the MSM-VAR and MSMH-VAR model, results are recorded in the following to make a comparison on which model able to given a more reliable and significance result.

TABLE III
Comparison of the MSM(2)-VAR(1) and MSMH(2)-VAR(1) model

Criterion	MSM(2)-VAR(1) model	MSMH(2)-VAR(1) model
Log Likelihood	2163.1114	2319.4936
AIC	-15.6128	-16.6231
HQ	-15.2307	-16.1280
SC	-14.6614	-15.3904

According to the results that summarizes in the table above, AIC, HQ and SC of the MSMH-VAR model able to provide approximate value than MSM-VAR model when estimate the relationship model between the variables of OP, GP, KLCI, STI, SETI and JCI. Generally, it is a common misconception that the log-likelihood value must be negative and the AIC value is positive; but if the likelihood is derived from the probability density then it is reasonable for the value is exceed 1 or a positive log-likelihood, and hence has a negative AIC. In algebraically, lower AIC is represent the better performance of the model, thus the more negative value of AIC which recorded by MSMH(2)-VAR(1) model able to provide a more significance results compare to MSM(2)-VAR(1) model. This is proven by HQ and SC outputs. Moreover, MSMH(2)-VAR(1) model has a higher log-likelihood than MSMH(2)-VAR(1), therefore MSMH-VAR model can be concluded as more suitable than MSM-VAR model in estimate the commodity price effect on KLCI, STI, SETI and JCI market index.

IV. CONCLUSION

In this paper, MS-VAR model that proposed by Krolzig is used in analysis the commodity price that are oil price and gold price effect on the four selected South-East Asia countries stock market index from December 1989 until May 2012. The two regime markov switching model with first autoregressive order is used in estimate the economic

relationship model. First regime in this paper is the recession state while the second regime represent to the growth state. Markov switching vector autoregressive models with mean adjusted after a shift are applied in study the relationship between commodity price effect and stock market returns on Malaysia, Singapore, Thailand and Indonesia. While all the data including World oil price, world gold price, Malaysia stock market index, Singapore stock market index, Thailand stock market index and Indonesia stock market index are taken from DATASTREAM and transform into a natural logarithm form before start the estimation. Oil price and gold price are proved that able to affect the stock market index on Malaysia, Singapore, Thailand and Indonesia.

ACKNOWLEDGMENT

The authors wish to thanks to their respective university for the financial support and computing facilities that make the works possible to be completed.

REFERENCES

[1] J. Fan, and Q. Yao, *Nonlinear Time Series: Nonparametric and Parametric Methods.* New York: Springer, 2003.

[2] J. D. Hamilton, “A new approach to the economic analysis of nonstationary time series and the business cycle,” *Econometrica*, vol. 57, pp. 357-384, 1989.

[3] H. M. Krolzig,. *Markov-switching Vector Autoregression*. Berlin: Springer, 1997.

[4] R. Sauter and S. Awerbuch, “Oil Price Volatility and Economic Activity: A Survey And Literature Review,” *IEA Research Paper*, International Energy Agency, Paris, August 2003

[5] R. Bhar, and S. Hammoudeh, “Commodities and financial variables : Analyzing relationship in a changing regime environment,” *International Review of Economics and Finance*, vol. 20, pp. 469-484, 2011.