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Research Paper

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Univariate Modeling of Indonesian Economic Growth Movement Using Markov Switching in Mean – Autoregressive

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Abstract— The purpose of this research is to construct a model of the Indonesia economic growth movement. Data used is economic growth rate (year on year, in percent) from the 1983 1st quarter – 2020 3rd quarter. Data sourced is Statistics Indonesia. The model used to construct the economic growth movement is Markov Switching in Mean - Autoregressive (MSM-AR) Model. The results of this research are that MSM-AR(3) was able to fit the recession signal according to the period of the economic crisis in 1998 and the period of the COVID-19 pandemic. By using the MSM-AR(3) model, it can be predicted that in the 4th quarter of 2020, the economic condition is still in the recession regime because of the COVID-19 pandemic. In 2021, MSM-AR(3) predicts that there is an economic recovery. It is indicated by positive economic growth forecasting and increasing every quarter, and the probability of a recession regime reach more than 0.5 per quarter.

Keywords- Markov, switching, growth, transition, autoregressive

I. INTRODUCTION

Economic growth is the ability of an economy to produce goods and services by using input factors including capital, labor, natural resources, and technology [3], [14]. Economic growth shows changes in the capacity to produce goods and services from time to time. The ideal economy is an economy that is growing continuously. But, in reality, this is not happening. The economy often fluctuates [4] and does not always suitable as targeted. Indonesia is an open economy country, so it is very vulnerable to external influences. Those have an impact on the stability of the domestic economy. Economic policy is needed to maintain the economy. Some economic policies that can be applied are fiscal policy and monetary policy. The fiscal policy such using various government spending and tax instruments to increase output so and reduce unemployment. Meanwhile, monetary policy maintains the stability of the exchange rate by controlling the money supply and interest rate.

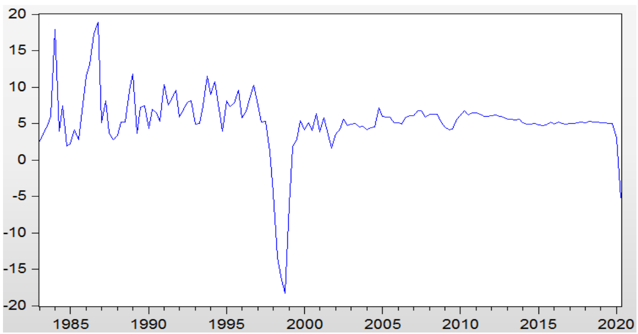

Figure 1. Movement of Economic Growth During Period 1983Q1 - 2020Q3

It has an implication, that there is an economic growth movement that reflects the economic phenomena in Indonesia. When the economic crisis in 1998, economic growth from quarter 1 to quarter 4 was negative. Then, during the COVID-19 pandemic, economic growth in quarter 2nd and quarter 3th were also negative. This is visualized in Figure 1.

The state of economic growth, which is visually presented in Figure 1, shows two state conditions, namely conditions when economic growth is negative (referred to as recession regimes) and conditions when economic growth is positive (referred to as expansion regimes). Because these two conditions can occur alternately so that they can be used as a proxy for the business cycle, and using the Markov assumption that economic growth conditions at time t are influenced by conditions $t-1$ and current conditions t affect conditions at $t+1$. Therefore, in the research, the writer applies the Markovian model, namely the Markov switching in the mean - autoregressive model, to model the movement of Indonesia's economic growth. In the application of the Markovian model, in addition to forecasting values for the observed variables, it also produces the transition matrix, the duration, and the probability of certain regimes (unobservable variables), to obtain predictions of economic conditions that occur in the future.

II. RELATED WORK

Markov model is a stochastic process where the probability of future events is influenced by the probability of current events. Study of the business cycle with Markov chain in time series model first was pioneered by Hamilton [7], [8],

[9], [10], [11]. His research used the growth of real Gross National Product from the period 1952Q2 - 1984Q4 as a business cycle proxy of the United States of America and proposes the Markov switching autoregressive model for business cycle modeling. His research suggests that the business cycle is better characterized by recurring patterns between recession and expansion regimes than by positive lag coefficients in the autoregressive model. Besides that, he suggests that the business cycle periodization based on the Markov switching autoregressive model is similar to the business cycle official calendar of NBER [18].

Meanwhile, Goodwin adopts Markov Switching Autoregressive (MS-AR) Model to analyze the business cycle using data of real Gross National Product growth (in 8 countries, that are USA, UK, Germany, Japan, Canada, Switzerland, Italy, and France). He shows that the MS-AR model is unable to capture nonlinearities in some economies. The filter and smoothed probability of the model indicate a turning point in the business cycle that is very close to them generated by the traditional method (NBER approach). Furthermore, asymmetric business cycles occur in all economies, except in German [6]. Meanwhile, Reference [19] shows that real GDP growth (economic growth) which is used as a business cycle proxy by applying MS-AR(2) model can capture the dynamics of the changes of expansion and recession regime compared to the AR model.

Applied three regimes (low, medium, and high growth rates) in the Markov Switching model is carried out by Medhioub [16]. He constructs a model of the Tunisian business cycle by applying the MSIH-AR (Markov Switching Intercept Heteroscedasticity - Autoregressive) model in industrial production index growth as a business cycle proxy. The results show that the model with three regimes represents the behavior of the business cycle better than the model with two regimes.

Moolman [17] used a different Markov Switching Model, which is the transition matrix that moves all along time points on real GDP growth to observe the dynamics of the South African business cycle. The result of his research is that model can distinguish between recession and expansion regimes in the business cycle.

Meanwhile, research about a comparison of Markov switching, Logit, and Probit models in USA business cycle modeling was carried out by Layton and Katsuura [15]. They use the coincident gauge, short-range gauge, and long-range gauge that are composite indicators sourced from Economic Cycle Research Institute. They show that Markov Switching Model has slightly better performance than the two models (Logit and Probit). Fritsche and Kuzin [5] compared the turning point prediction of the German business cycle using the industrial production index (from 1978 to 2002). To do this, they used Probit and Markov Switching Models. This research concluded that the two models result from similar turning point predictions.

III. METHODOLOGY

Data Source

Data used in this research is the year-on-year economic growth for the 1st quarter of 1983 to the 3rd quarter of 2020, which is derived from GDP at constant prices (2010 = 100). Data from the 1st quarter of 1983 to the 2nd quarter of 2020 are training data. On the other hand, data from the 3rd quarter of 2020 are used as testing data.

Analysis Tools

Markov Chain

There is a latent random variable $s_t \in \{1,2,\dots,r\}$ ($r \geq 2$ and *finite*), probability $s_t = w$ depends on past time s_{t-1}, can be written as:

$$p(s_t = w|s_{t-1} = v, s_{t-2} = h, \dots) = p(s_t = w|s_{t-1} = v) = p_{vw}\,;\;\; v, w = 1,2,\dots,r$$

The above process states that there is a Markov chain of r regimes or states with a transition probability p_{vw}. It means that the probability of v regime will be followed by a w regime.

$$\sum_{w=1}^{r} p_{vw} = 1$$

The matrix of transition probability is [2]:

$$P = \begin{pmatrix} p_{11} & \cdots & p_{r1} \\ \vdots & \ddots & \vdots \\ p_{1r} & \cdots & p_{rr} \end{pmatrix},$$

It is assumed that Markov processes are homogeneous and irreducible, so that for all v and transition probability matrix is ergodic. It means that one of the eigenvalues is one, while others are in a unit circle. This study uses two regimes, namely recession regime and expansion regime, so that the transition probability matrix:

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix}.$$

with:

$p(s_t = 1|s_{t-1} = 1) = p_{11};\;\; p(s_t = 2|s_{t-1} = 1) = p_{12};$
$p(s_t = 1|s_{t-1} = 2) = p_{21}; p(s_t = 2|s_{t-1} = 2) = p_{22};$
$vec\,(P) = p = (p_{11}\, p_{12}\, p_{21} p_{22})'.$

The s_t regime is not observed, so the likelihood function of data $p(x_T, x_{T-1}, \dots, x_1; p, \Theta)$ must be maximized. In this study, The business cycle has two regimes, namely recession, and expansion. The recession regime ($s_t = 1$) is defined as the economic growth is less than or equal to zero ($x_t \leq 0$) and the expansion regime ($s_t = 0$) is defined as the economic growth is positive ($x_t > 0$).

To predict future probability in the Markov chain framework, a transition probability matrix (two regimes) ξ future period in $\boldsymbol{P}^{\xi}$ future period is formed. These are the steps:

1. $\boldsymbol{P}$ transition probability matrix with two regimes:
$$\boldsymbol{P} = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} = \begin{pmatrix} p_{11} & 1 - p_{11} \\ 1 - p_{22} & p_{22} \end{pmatrix}$$
2. The characteristic equation form to get eigenvalues of $\boldsymbol{P}$

$$|\boldsymbol{P} - \varpi \boldsymbol{I}| = \begin{vmatrix} p_{11} - \varpi & 1 - p_{11} \\ 1 - p_{22} & p_{22} - \varpi \end{vmatrix} = 0$$
$$= (p_{11} - \varpi)(p_{22} - \varpi) - (1 - p_{11})(1 - p_{22}) = 0$$
$$= p_{11}p_{22} - (p_{11} + p_{22})\varpi + \varpi^2 - 1 + p_{11} + p_{22} - p_{11}p_{22} = 0$$
$$= \varpi^2 - (p_{11} + p_{22})\varpi - 1 + p_{11} + p_{22} = 0$$
$$= (\varpi - 1)(\varpi + 1 - p_{11} - p_{22}) = 0$$

So:

Eigen value of $\boldsymbol{P}$ is $\varpi_1 = 1$ and $\varpi_2 = -1 + p_{11} + p_{22}$.

3. Use the decomposition method to express $\boldsymbol{P}^{\xi}$

$$\boldsymbol{P}^{\xi} = (\varpi_1)^{\xi}\boldsymbol{E}_1 + (\varpi_2)^{\xi}\boldsymbol{E}_2 \quad (1)$$

With $\boldsymbol{E}_1$ and $\boldsymbol{E}_2$ are constituent matrixs of $\boldsymbol{P}$ that is formulated:

$$\boldsymbol{E}_1 = \frac{1}{\varpi_1 - \varpi_2}(\boldsymbol{P} - \varpi_2 \boldsymbol{I}) \text{ and}$$
$$\boldsymbol{E}_1 = \frac{1}{\varpi_2 - \varpi_1}(\boldsymbol{P} - \varpi_1 \boldsymbol{I})$$

so:

$$\boldsymbol{E}_1 = \frac{1}{2 - p_{11} - p_{22}}\begin{pmatrix} 1 - p_{22} & p_{12} \\ p_{21} & 1 - p_{11} \end{pmatrix}$$

and

$$\boldsymbol{E}_2 = \frac{1}{-2 + p_{11} + p_{22}} = \frac{1}{2 - p_{11} - p_{22}}\begin{pmatrix} p_{21} & -p_{12} \\ -p_{21} & p_{12} \end{pmatrix}$$

4. Put in $\varpi_1 = 1$ and $\varpi_2 = -1 + p_{11} + p_{22}$ into equation (1), becomes:

$$\boldsymbol{P}^{\xi} = \boldsymbol{E}_1 + (-1 + p_{11} + p_{22})^{\xi}\boldsymbol{E}_2$$

$$\boldsymbol{P}^{\xi} = \frac{1}{2 - p_{11} - p_{22}}\begin{pmatrix} 1 - p_{22} & p_{12} \\ p_{21} & 1 - p_{11} \end{pmatrix} + (-1 + p_{11} + p_{22})^{\xi}\left[\frac{1}{2 - p_{11} - p_{22}}\begin{pmatrix} p_{21} & -p_{12} \\ -p_{21} & p_{12} \end{pmatrix}\right]$$

$$\boldsymbol{P}^{\xi} = \frac{1}{2 - p_{11} - p_{22}}\left[\begin{pmatrix} 1 - p_{22} & p_{12} \\ p_{21} & 1 - p_{11} \end{pmatrix} + (-1 + p_{11} + p_{22})^{\xi}\begin{pmatrix} p_{21} & -p_{12} \\ -p_{21} & p_{12} \end{pmatrix}\right]$$

$$\boldsymbol{P}^{\xi} = \begin{pmatrix} \frac{(1 - p_{22}) + \kappa^{\xi}(1 - p_{11})}{2 - p_{11} - p_{22}} & \frac{(1 - p_{22}) - \kappa^{\xi}(1 - p_{22})}{2 - p_{11} - p_{22}} \\ \frac{(1 - p_{11}) - \kappa^{\xi}(1 - p_{11})}{2 - p_{11} - p_{22}} & \frac{(1 - p_{11}) + \kappa^{\xi}(1 - p_{22})}{2 - p_{11} - p_{22}} \end{pmatrix}$$

Where:

$$(s_{t+\xi} = 1 | s_t = 1) = \frac{(1 - p_{22}) + \kappa^{\xi}(1 - p_{11})}{1 - \kappa}$$
$$p(s_{t+\xi} = 1 | s_t = 2) = \frac{(1 - p_{22}) - \kappa^{\xi}(1 - p_{22})}{1 - \kappa}$$
$$p(s_{t+\xi} = 2 | s_t = 2) = \frac{(1 - p_{11}) + \kappa^{\xi}(1 - p_{22})}{1 - \kappa}$$
$$p(s_{t+\xi} = 2 | s_t = 1) = \frac{(1 - p_{11}) - \kappa^{\xi}(1 - p_{11})}{1 - \kappa}$$
$$\kappa = -1 + p_{11} + p_{22}$$

$p(s_{t+\xi} = 2 | s_t = 1)$ means if the current process takes place in regime 1, probability that ξ in future period will be in regime 2 is:

$$\frac{(1 - p_{22}) - \kappa^{\xi}(1 - p_{22})}{2 - p_{11} - p_{22}}$$

The transition matrix $\boldsymbol{P}$ is regular, if transition matrix in step to-ξ ($\xi > 0$) has elements that are all positive (*non-zero*). So, when the transition probability matrix $\boldsymbol{P}$ to the power ξ (positive integer), then the elements of $\boldsymbol{P}^{\xi}$ are positive. $\boldsymbol{P}^{\xi}$ has *limiting distribution*:

$$\lim_{\xi \to \infty} \boldsymbol{P}^{\xi} = \boldsymbol{P}^{*} \quad (3)$$

$\boldsymbol{P}^{*}$ is the *limiting distribution* of transition matrix. $\boldsymbol{P}^{*}$ has ergodic, where column from $\boldsymbol{P}^{*}$ is long-run probability in a regime. To calculate the average duration of a certain regime (expected duration) using a formula [7]:

$$D_v = \frac{1}{1 - p_{vv}},$$

- **Markov Switching in Mean-Autoregressive Model**

The MSM-AR model used by Hamilton to modeling the business cycle based on growth rate. MSM-AR (*d*) is formulated as follows [7]:

$$(x_t - \mu_{s_t}) = \varrho_1(x_{t-1} - \mu_{s_{t-1}}) + \cdots + \varrho_d(x_{t-d} - \mu_{s_{t-d}}) + \epsilon_t, \quad \epsilon_t \sim N(0, \sigma_{s_t}^2) \quad (4)$$

with: x_t: time series data (growth of real GDP year on year), ϱ_d: *autoregressive* coefficient in order *d*, μ_{s_t}: mean of economy growth in the regime s_t, $\sigma_{s_t}^2$: variance in the regime *s*, $s_t = 1, \ldots, r$, dan ϵ_t: random error.

The Markov switching model does not only involve actual observable values in the estimation process but also involves hidden probabilities. So that the Markov switching model not only produces a fitted value but also produces a probability value estimation, they are transition matrix, filtered probabilities, and smoothed probabilities.

Equation Estimation (1)

Equation (1) has density function as follows:

$$f(x_t | s_t, \ldots, s_{t-d}, \Omega_{t-1}; \Theta) = \frac{1}{\sigma_{s_t}\sqrt{2\pi}} \exp\left[-\frac{\left((x_t - \mu_{s_t}) - \varrho_1(x_{t-1} - \mu_{s_{t-1}}) - \cdots - \varrho_d(x_{t-d} - \mu_{s_{t-d}})\right)^2}{2\sigma_{s_t}^2}\right] \quad (5)$$

with: $\Omega_{t-1} = (x_{t-1}, \ldots, x_{t-d})$,
$\Theta = (\mu_{s_t}, \sigma_{s_t}^2, \varrho_1 \ldots \varrho_d, p_{11}, p_{12}, p_{21}, p_{22})$

On calculating the density function in equation (5), past information Ω_{t-1} and values of $s_t, s_{t-1}, \ldots, s_{t-d}$ which are unobserved variables (regime) are needed. To estimate parameters in equation (4), the density function joint of x_t with $s_t, \ldots, s_{t-d}$ must be formed based on Bayes' theorem, namely:

$$f(x_t, s_t, \dots, s_{t-d}|\Omega_{t-1};\Theta) = f(x_t|s_t, \dots, s_{t-d}, \Omega_{t-1};\Theta)P(s_t, \dots, s_{t-d}, \Omega_{t-1};\Theta) \quad (6)$$

From equation (5) formed the likelihood function:

$$\mathcal{L}(\Theta) = \sum_{t=d+1}^{T}\sum_{s_t=1}^{r}\dots\sum_{s_{t-d}=1}^{r}\log f(x_t, s_t, \dots, s_{t-d}|\Omega_{t-1};\Theta) \quad (7)$$

$$\mathcal{L}(\Theta) = \sum_{t=1}^{T}\log f(x_t|s_t, \dots, s_{t-d}, \Omega_{t-1};\Theta)P(s_t, \dots, s_{t-d}, \Omega_{t-1};\Theta) \quad (8)$$

To obtain parameter estimation in the Markov model, equation (8) must be maximized, then iteratively carried by filtering and smoothing processes.

Filtering

Filtering processes to obtain the probability of a regime at time t based on observational data at time t. This process is executed iteratively from $t = d+1, d+2, \dots, T$. The result of the filtering process is the value of filtered probabilities [12],[13]:

$$P(s_t, \dots, s_{t-d}, \Omega_t;\theta) = \frac{f(x_t|s_t, \dots, s_{t-d}, \Omega_{t-1};\theta)P(s_t, \dots, s_{t-d}, \Omega_{t-1};\theta)}{\sum_{s_t=1}^{r}\dots\sum_{s_{t-d}=1}^{r} f(x_t|s_t, \dots, s_{t-d}, \Omega_{t-1};\theta)P(s_t, \dots, s_{t-d}, \Omega_{t-1};\theta)} \quad (9)$$

So, the filtered probabilities can be calculated by:

$$\mathrm{P}(\mathrm{s}_t = \mathrm{w}|\Omega_t;\Theta) = \sum_{\mathrm{s}_t=\mathrm{w}}^{\mathrm{r}}\dots\sum_{\mathrm{s}_{t-d}=\mathrm{w}}^{\mathrm{r}}\mathrm{P}(\mathrm{s}_t, \dots, \mathrm{s}_{t-d}, \Omega_{t-1};\Theta)$$

Smoothing

Estimate the probability regime can be improved by using all information in the sample. In the smoothing process, estimate the probability regime in period t using the information set in the final period. This is different from the filtering step which uses the information then or contemporaneous information. Intuitively, using information about future realization of dependent variable $y_s(s > t)$ increases the accuracy of estimation in n regimes in period t. It occurs because the transition probability matrix relates simultaneously to the likelihood function at different periods. Kim shows that [12], [13]:

$$P(s_t = i, s_{t+1} = j\,|I_T) = P(s_t = i\,|s_{t+1} = j, I_T)P(s_{t+1} = j\,|I_T) \quad (15)$$

$$= \frac{P(s_t = i, s_{t+1} = j\,|I_t)}{P(s_{t+1} = j\,|I_t)}P(s_t = j\,|I_T) \quad (16)$$

Equation (15) moves to equation (16). It shows that if s_{t+1} is known, there is no additional information about s_t in $y_{t+1}, \dots, y_T$. Smoothed probability, $P(s_t = i|I_T)$, in period t is determined by marginalizing the joint probability to s_{t+1}:

$$P(s_t = i|I_T) = \sum_{j=1}^{N}P(s_t = i, s_{t+1} = j|I_T) \quad (17)$$

Smoothed probabilities to $t = T-1, T-2, \dots, d+1$ iteration based on:

$$P(s_t = w|\Omega_T;\Theta) = \sum_{v=1}^{r}\frac{p(s_t = w|x_t;\varsigma_{(f)})\,p(s_{t+1} = v|x_T;\varsigma_{(f)})\,p_{vw}^{(f)}}{p(s_{t+1} = v|x_t;\varsigma_{(f)})} \quad (18)$$

for $t = T-1$, $p(s_{t+1} = v|x_T;\varsigma_{(f)}) = p(s_T = v|x_T;\varsigma_{(f)})$ starting point in smoothing step.

- **Model Validity Checking**

Wald Statistic

Wald Statistic used to check the model validity, which is estimated by using restrictions on the parameters in the model, namely:

$$H_0: \psi_{s_t} = 0 \text{ versus } H_1: \psi_{s_t} \neq 0$$

with: $\psi_{s_t} = (\mu_{s_t}, \varrho_1, \varrho_2, \dots, \varrho_d)'$. Wald Statistic is formulated as follows:

$$WS = \psi_{s_t}'(V^2(h_t h_t')^{-1}\psi_{s_t}$$

where:

$V^2 = \frac{sum\ squared\ residual \text{ from equation (70)}}{T-k}$;

k: number of parameters in $\mathrm{MSM-AR}(d)$.

WS asymptotically distributed χ^2 with degrees of freedom d +2 and equivalent to F-statistic if WS divided by its degrees of freedom.

Transition Matrix Checking

According to Goodwin [6], p_{11} or p_{22} is the transition matrix element, this is also one of the parameters generated by the MSM-AR model (d)). He argues that when p_{11} or p_{22} is zero or exactly one, MSM-AR(d) model is not can be applied to see regime change (dating turning point). It occurred because the process will go to one regime. It means that the transition matrix does not reach the limiting distribution. On the other hand, if p_{11} or p_{22} are close to one, the transition matrix produced by the model candidate is irreducible.

Model Selection Criteria

To determine best model used for further analysis in this research, authors use AIC [1], which is formulated as follows:

$$-2\left(\frac{\log(likelihood\ of\ model)}{number\ of\ observations}\right) + 2\left(\frac{number\ of\ parameter}{number\ of\ observations}\right)$$

The selected model is based on minimum AIC value.

IV. RESULTS AND DISCUSSION

Table 4.1 presents the estimation results of the MSM-AR (1), MSM-AR (2), MSM-AR (3), and MSM-AR (4) models. Based on the estimation result for all the model candidates, it can be seen that all model candidates have met the validity because the Wald statistics generated from all models are significant at the 5% alpha level. It means that the model can be analyzed further. Meanwhile, when viewed from the transition matrix, the p_{11} and p_{22} values generated by all model candidates are less than one, so there is no probability that they are not absorbed in one particular regime. Implicitly, the transition matrix has a limiting distribution or a certain probability regime in the long run.

Table 4.1 Estimation Results of MSM-AR Based on Economy Growth Data YoY Indonesia, 1983Q1 – 2020Q3

	MSM-AR(1)	MSM-AR(2)	MSM-AR(3)	MSM-AR(4)
μ_1	-2.4332 [0.1369]	-3.401590 [0.0712]	**-2.772326 [0.0050]**	**-2.713532 [0.0034]**
μ_2	**6.5365 [0.0000]**	**6.398602 [0.0002]**	**6.166657 [0.0000]**	**6.197160 [0.0000]**
ϱ_1	**0.8872 [0.0000]**	**0.696719 [0.0000]**	**1.094782 [0.0000]**	**1.088190 [0.0000]**
ϱ_2	-	0.203241 [0.0271]	-0.180924 [0.2353]	-0.206551 [0.1431]
ϱ_3	-	-	-0.113535 [0.2443]	0.010744 [0.9336]
ϱ_4	-	-	-	-0.110102 [0.1785]
ϱ_5	-	-	-	-
Log(σ)	**0.7012 [0.0000]**	**0.707018 [0.0000]**	**0.653996 [0.0000]**	**0.644626 [0.0000]**
Wald Statistic	**534.5592 [0.0000]**	**621.8916 [0.0000]**	**451.7779 [0.0000]**	**537.0867 [0.0000]**
AIC	4.741914	4.738007	**4.687537**	4.688304
MSDP	0.122277354	0.119922414	0.065342728	0.10436576
p_{11} (resesi)	0.836836	0.858285	0.728705	0.729293
p_{22} (ekspansi)	0.954932	0.961842	0.956524	0.956495
Expected duration of recession	6.128800	7.056432	3.686026	3.694029
Expected duration of expansion	22.18859	26.20658	23.00119606	22.98581
Expected of the period cycle	28.3174956	33.2632403	26.6872205	26.6798945

Note: […] is p-value

Based on the AIC value of the MSM-AR model candidate, it turns out that the MSM-AR model (3) has a minimum AIC value, so this model is used for further analysis. Based on MSM-AR (3), information on the average economic growth in both the recession and expansion regimes during the 1983Q1 - 2020Q3 observation period were -2.77% and 6.17%, respectively. (Both values are significant at the alpha level of 5%) This indicates that in a recession regime, economic growth is negative, which means a decrease in national output so that the economy contracts. Meanwhile, the economic growth expansion regime is positive, which means an increase in national output.

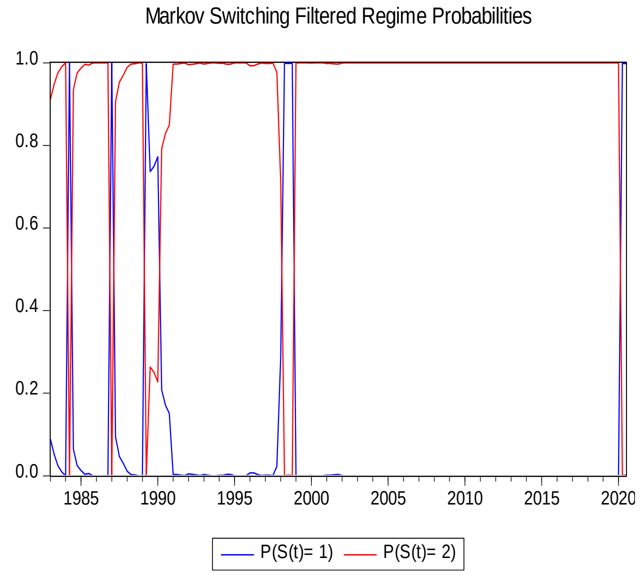

Figure 2. The Movement of filtered probilities of MSM-AR(3)

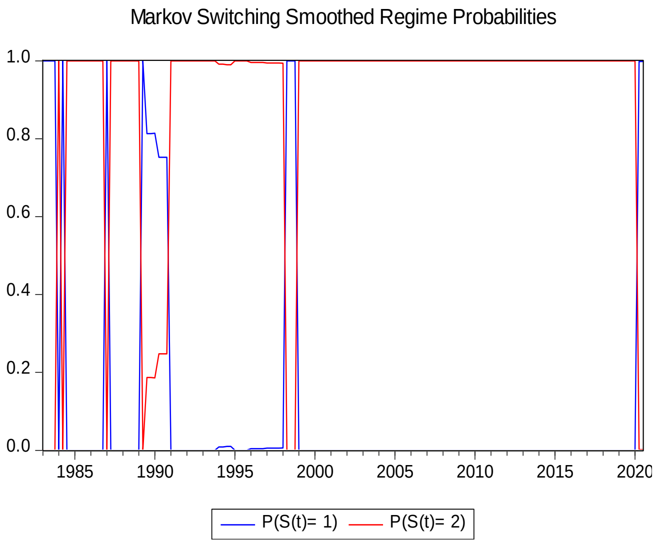

Figure 3. The Movement of smoothed probilities of MSM-AR(3)

Based on Figures 2 and 3, show that the probability of filtered and smoothed moving in the same direction coherently. MSM-AR(3) accurately gives signals regime of economic crisis recession in the second, third and fourth quarters of 2018 and recession due to COVID-19 in the second quarter of 2020. The duration of recession and expansion regimes are 3.69 and 23.00 quarters. It means that the average duration of the economic recession is 3.69 quarters and the average duration of economic expansion is 23.00 quarters. So, the business cycle duration is almost 27 quarters (over 6.5 years). Because the business cycle characteristic is current but not periodic, so the cycle duration is not regular/periodic. It is reinforced from the data movement showing there is no regular pattern in fixed time intervals in Figure 4 and generally according to several studies shows that the duration of the business cycle varies.

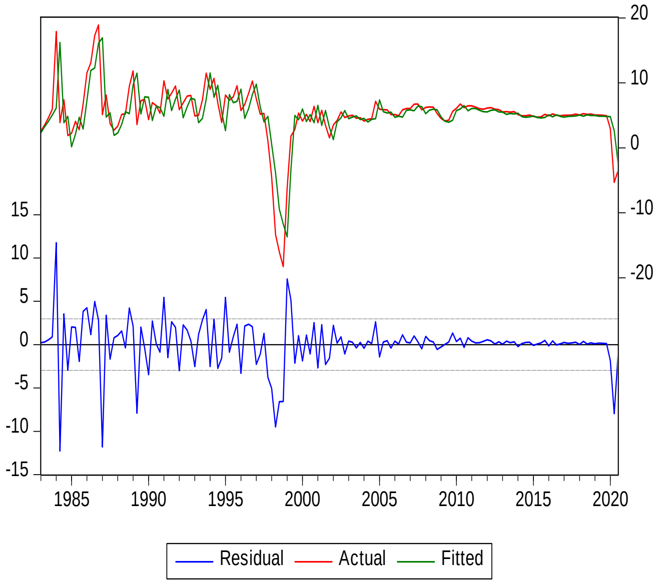

Figure 4 Movement of actual, fitted, and residual value of MSM-AR(3)

The transition matrix of MSM-AR(3) model is as follows:

Table 2 Transition Matrixs of MSM-AR(3) model

	Recession Regime	Expansion Regime
Recession Regime	0.728705	0.271295
Expansion Regime	0.043476	0.956524

Sourced: processed by researcher

The transition matrix in table 2 is irreducible. It means that is no absorbed in one particular regime. It is known from value of $p_{11} < 1$ and $p_{22} < 1$. Interpretation of transition matrix is that probability of regime change from recession to expansion is 27.13%. While the probability of regime change from expansion to recession is 4.35%. It shows that the economy in a recession tends to shift to an expansionary regime rather quickly, rather than the other way around. It is in line with the average duration when the economy was in the recession regime of about 3.69 quarters shorter than the average duration when the economy was in the expansion regime of around 23.00 quarters.

Based on the transition matrix, the probability of a recession and expansion regime in 4th quarter of 2020 to 4th quarter of 2021 can be estimated (PR_t and PE_t, see table 3). In the 4th quarter of 2020 and the 1st quarter of 2021, the Indonesian economy is still in a recession regime. This is indicated by the probability of PR_t is more than 0.5. However, the economy shows a signal towards expansion regime in 2nd quarter to 4th quarter. This is indicated by PE_t is more than 0.5, so it can be interpreted that economy towards recovery direction after affected by the COVID-19 pandemic.

The forecasting of Indonesia's economic growth in the fourth quarter of 2020 is produced by MSM-AR (3) is -0.3119%, where the value of the growth is still negative, so it can be interpreted that the economy in the 4th quarter of 2020 is still in a recession regime. Meanwhile, the forecast for economic growth in the 1st - 4th quarter of 2021 is 1.77%, 3.03%, 3.78%, and 4.21% (positive value) and an increase every quarter, which means there is a recovery in 2021.

Table 3 Forecasting Values of Economic Growth, PR_t, and PE_t

Year	Quarter	Forecasting of Economic Growth (%)	Forecasting of probability when t is recession, so t+1 is (PR_t)	Forecasting of probability when t is recession, so t+1is (PE_t)
2020	IV	-0.311935	0.728705	0.271295
2021	I	1.772808	0.542806	0.457194
	II	3.030782	0.415422	0.584578
	III	3.779383	0.328135	0.671865
	IV	4.209610	0.268324	0.731676

V. CONCLUSION AND FUTURE SCOPE

The Markov Switching in Mean – Autoregressive Model is can be applied to the Indonesian economic growth movement. The model specification is MSM-AR(3). Wald statistic indicates the model is valid, and its transition matrix is irreducible. This model can fit the recession regime according to the economic crisis in 1998 and the COVID-19 pandemic in 2020.

By using the MSM-AR model (3), it can be predicted that in the 4th quarter of 2020 the economic condition is still experiencing the recession regime due to the impact of the COVID-19 pandemic. In 2021, MSM-AR (3) predicts that the economy will recover, which means economic conditions during the first to fourth quarter will enter an expansion regime. It is indicated by the positive economic growth forecast which shows an increase every quarter, and the probability of a recession regime reach more than 0.5 per quarter.

Stakeholders can formulate policies and controlled the expansion program by concerning into availability of the budget. In 2021, the economy is a recovery signal after affected by the COVID-19 pandemic. Lockdowns or large-scale social restrictions can economy sluggish, so those policies need to be reviewed. Optimizing the implementation of health protocols, vaccinations, and limiting information about the dangers of COVID-19 are some ways that make the economy recover quickly.

Further research needs to include exogenous variables that influence economic growth, such as exports, inflation, etc. Those can increase the accuracy of forecasting. Furthermore, nowcasting and real-time forecasting of economic growth need to be constructed by accommodating data from Google Trend so that it can construct the current economic conditions models.

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