

SULIT



First Semester Examination
2018/2019 Academic Session

December 2018/January 2019

**MSG467 - Time Series Analysis
(Analisis Siri Masa)**

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of **SEVENTEEN (17)** pages of printed material before you begin the examination.

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Instructions: Answer **FOUR (4)** questions.

[Arahan: Jawab **EMPAT (4)** soalan.]

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai].

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Question 1

- (a) (i) Define invertibility conditions for an ARMA model in terms of summability of the polynomial coefficients of the infinite form of the model.
- (ii) Explain the use of ACF and PACF in determining the type and order of ARIMA model.
- (iii) Explain the methods that can be used to check for stationarity of time series data in terms of its mean and variance.
- (iv) Briefly explain the necessity of conducting diagnostic checking in building up a time series model. Also explain the difference between derivation of a new model and overfitting.

[45 marks]

- (b) Let Y_t be a process defined as: $Y_t = \varepsilon_t - \theta\varepsilon_{t-1} - \theta\varepsilon_{t-2} - \dots - \theta\varepsilon_2 - \theta\varepsilon_1$ where $\varepsilon_t \sim \text{NID}(0, \sigma_\varepsilon^2)$.

- (i) Determine the variance of the process.
- (ii) Investigate stationarity of the process.

[30 marks]

- (c) Rewrite each of the models below using the backward operator B and state the form of ARIMA(p, d, q) or SARIMA(p, d, q)(P, D, Q). [$p, d, q, P, D,$ and Q are positive finite numbers].

- (i) $Y_t = \varepsilon_t - \theta(Y_{t-1} - \varepsilon_{t-1}) + \phi(Y_{t-2} + \varepsilon_{t-2}) - \lambda Y_{t-3}$
- (ii) $Y_t = (1 + \phi)Y_{t-1} - \theta\varepsilon_{t-1} - (\phi + \lambda)Y_{t-2} + \lambda(Y_{t-3} + \varepsilon_{t-2})$
- (iii) $Y_t = \varepsilon_t + (1 + \theta_1)\varepsilon_{t-1} + (1 + \theta_1 - \theta_2)\varepsilon_{t-2} + (1 + \theta_1 - \theta_2)\varepsilon_{t-3} + (1 + \theta_1 - \theta_2)\varepsilon_{t-4} + \dots$
- (iv) $Y_t = (1 + \phi_1)Y_{t-12} - (\phi_1 + \phi_2)Y_{t-24} + \phi_2 Y_{t-36} + \varepsilon_t - \theta_1\varepsilon_{t-2} + \theta_2\varepsilon_{t-12} - \theta_1\theta_2\varepsilon_{t-14}$

[25 marks]

...3/-

Soalan 1

- (a) (i) Definisikan syarat ketersongsangan bagi suatu model ARMA dalam sebutan keterhasiltambahan bagi koefisien polinomial bagi bentuk tak terhingga model tersebut.
- (ii) Bincangkan penggunaan ACF dan PACF bagi menentukan jenis dan pangkat model ARIMA.
- (iii) Jelaskan kaedah yang boleh digunakan untuk memeriksa kepegunan bagi data siri masa daripada segi min dan varians.
- (iv) Jelaskan secara ringkas keperluan menjalankan pemeriksaan diagnostik semasa membina model siri masa. Juga jelaskan perbezaan antara terbitan model baru dan melebihi suai.

[45 markah]

- (b) Andaikan Y_t suatu proses yang ditakrifkan sebagai:
 $Y_t = \varepsilon_t - \theta\varepsilon_{t-1} - \theta\varepsilon_{t-2} - \dots - \theta\varepsilon_2 - \theta\varepsilon_1$ yang mana $\varepsilon_t \sim \text{NID}(0, \sigma_\varepsilon^2)$.

- (i) Tentukan varians bagi proses tersebut.
- (ii) Kaji kepegunan proses tersebut.

[30 markah]

- (c) Tulis semula setiap model di bawah dengan menggunakan pengoperasi anjak ke belakang B dan nyatakan bentuk ARIMA(p,d,q) atau SARIMA(p,d,q)(P,D,Q). [p, d, q, P, D dan Q adalah nombor-nombor positif terhingga]

- (i) $Y_t = \varepsilon_t - \theta(Y_{t-1} - \varepsilon_{t-1}) + \phi(Y_{t-2} + \varepsilon_{t-2}) - \lambda Y_{t-3}$
- (ii) $Y_t = (1 + \phi)Y_{t-1} - \theta\varepsilon_{t-1} - (\phi + \lambda)Y_{t-2} + \lambda(Y_{t-3} + \varepsilon_{t-2})$
- (iii) $Y_t = \varepsilon_t + (1 + \theta_1)\varepsilon_{t-1} + (1 + \theta_1 - \theta_2)\varepsilon_{t-2} + (1 + \theta_1 - \theta_2)\varepsilon_{t-3} + (1 + \theta_1 - \theta_2)\varepsilon_{t-4} + \dots$
- (iv) $Y_t = (1 + \phi_1)Y_{t-12} - (\phi_1 + \phi_2)Y_{t-24} + \phi_2 Y_{t-36} + \varepsilon_t - \theta_1\varepsilon_{t-2} + \theta_2\varepsilon_{t-12} - \theta_1\theta_2\varepsilon_{t-14}$

[25 markah]

...4/-

Question 2

- (a) Consider the following ARMA(1,2) process: $Y_t = \phi Y_{t-1} + \varepsilon_t - \theta \varepsilon_{t-2}$ where $\varepsilon_t \sim \text{NID}(0, \sigma_\varepsilon^2)$.

(i) By expressing the process in AR(∞) form, determine the required invertibility condition for Y_t .

(ii) Show that $\gamma_0 = \frac{(1 - 2\phi^2\theta + \theta^2)}{1 - \phi^2}$. Use the expression to obtain the stationarity condition for Y_t .

[25 marks]

- (b) Consider an ARMA(2,1) process: $(1 - \phi_1 B - \phi_2 B^2)Y_t = (1 - \theta B)\varepsilon_t$

(i) Show that $\gamma_1 = \frac{\phi_1 \gamma_0 - \theta_1 \sigma_\varepsilon^2}{1 - \phi_2}$.

(ii) Obtain the specific and general expressions for the autocovariance function.

(iii) A time series of 300 observations was fitted with an ARMA(2,1) model, producing the following model:

$$Y_t = 0.7Y_{t-1} + 0.08Y_{t-2} + \varepsilon_t + 0.2\varepsilon_{t-1} \quad \text{where } \varepsilon_t \sim \text{NID}(0, 3)$$

Estimate the values of autocorrelation, ACF for lag $k = 1, 2, 3, 4, 5$, and partial autocorrelation, PACF for lag $k = 1$ and 2.

(iv) Draw the sample ACF and PACF and give comment on the features observed. Is the ARMA(2,1) an appropriate model for the series? Is there a more parsimonious ARMA model that can be fitted to the series?

(v) What is the estimate for the variance of the series from part (iii) above? If the process can be approximated as an AR(1), estimate the variance.

[Given the values of ACF for lag 6 through to lag 10 are 0.152, 0.109, 0.092, 0.054 and 0.066 respectively, while PACF for lag 3 through to lag 10 are -0.036, -0.049, -0.040, -0.046, 0.042, 0.053, -0.043, and 0.061 respectively].

[50 marks]

- (c) Consider the following seasonal process with period four: $Y_t = \varepsilon_t - \theta \varepsilon_{t-4}$. Show that the ACF cuts off at lag 4 and the PACF tails off exponentially seasonally with non-zero values at lags $k = 4, 8, 12, \dots$.

[25 marks]

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Soalan 2

(a) Pertimbangkan proses ARMA(1,2) yang berikut: $Y_t = \phi Y_{t-1} + \varepsilon_t - \theta \varepsilon_{t-2}$ yang mana $\varepsilon_t \sim \text{NID}(0, \sigma_\varepsilon^2)$.

(i) Dengan mengungkapkan proses dalam bentuk AR(∞), tentukan syarat keterhasiltambahan yang diperlukan bagi Y_t .

(ii) Tunjukkan bahawa $\gamma_0 = \frac{(1 - 2\phi^2\theta + \theta^2)}{1 - \phi^2}$. Guna ungkapan tersebut untuk mendapatkan syarat kepegungan bagi Y_t .

[25 markah]

(b) Pertimbangkan proses ARMA(2,1): $(1 - \phi_1 B - \phi_2 B^2) Y_t = (1 - \theta B) \varepsilon_t$

(i) Tunjukkan bahawa $\gamma_1 = \frac{\phi_1 \gamma_0 - \theta_1 \sigma_\varepsilon^2}{1 - \phi_2}$.

(ii) Dapatkan ungkapan khusus dan umum untuk fungsi autokovarians.

(iii) Suatu siri masa dengan 300 cerapan telah disuai dengan suatu model ARMA(2,1), menghasilkan model berikut:

$$Y_t = 0.7Y_{t-1} + 0.08Y_{t-2} + \varepsilon_t + 0.2\varepsilon_{t-1} \quad \text{yang mana } \varepsilon_t \sim \text{NID}(0, 3)$$

Anggarkan nilai bagi autokorelasi, ACF untuk susulan $k = 1, 2, 3, 4, 5$, dan autokorelasi separa, PACF untuk susulan $k = 1$ dan 2 .

(iv) Lukiskan sampel ACF dan PACF, dan beri komen mengenai ciri yang diperhatikan. Adakah model ARMA(2,1) sesuai untuk siri tersebut? Adakah terdapat model ARMA yang lebih parsimoni yang boleh disuaikan pada siri tersebut?

(v) Apakah anggaran untuk varians bagi siri tersebut daripada bahagian (iii) di atas? Jika proses tersebut boleh dihampirkan sebagai AR(1), anggaran nilai varians.

[Diberi nilai ACF bagi susulan 6 hingga 10 adalah masing-masing 0.152, 0.109, 0.092, 0.054 and 0.066 manakala PACF untuk susulan 3 hingga 8 adalah masing-masing -0.036, -0.049, -0.040, -0.046, 0.042, 0.053, -0.043, dan 0.061].

[50 markah]

(c) Pertimbangkan proses bermusim berikut dengan jangkamasa empat: $Y_t = \varepsilon_t - \theta \varepsilon_{t-4}$. Tunjukkan bahawa ACF terpangkas pada susulan ke-4 dan PACF menyusut secara eksponen dengan nilai bukan sifar pada susulan $k = 4, 8, 12, \dots$.

[25 markah]

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Question 3

- (a) Consider the following SAR(2) model for seasonal data with period 6:

$$Y_t = \phi_1 Y_{t-6} + \phi_2 Y_{t-12} + \varepsilon_t.$$

Show that the least squares estimates for ϕ_1 and ϕ_2 are given by:

$$\hat{\phi}_1 = \frac{\hat{\rho}_6(1 - \hat{\rho}_{12})}{1 - \hat{\rho}_6^2} \quad \text{and} \quad \hat{\phi}_2 = \frac{\hat{\rho}_{12} - \hat{\rho}_6^2}{1 - \hat{\rho}_6^2}$$

[30 marks]

- (b) Three sets of time series data: P, Q and R were collected and to be fitted with time series models. The ACF and PACF of the three series are given in Table 1, Table 2 and Table 3 in Appendix A.

- (i) Which series exhibit seasonal characteristic? What is the seasonal period for the series?
- (ii) Determine the appropriate model for each of the series. Give your reasons.
- (iii) Calculate the estimate for the coefficients of the model and the corresponding variance of the errors.

[30 marks]

- (c) A finance researcher attempts to find a model characterizing the returns and volatility of the highly influenced US stock index. Appendix B shows the output of his analyses that can be divided into four main stages.

Discuss the findings of the analysis at each stage. In particular, discuss any evidence for asymmetric and leverage effects as well as evidence to support the Capital Asset Pricing Model (CAPM).

[40 marks]

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Soalan 3

- (a) Pertimbangkan model SAR(2) yang berikut untuk data bermusim dengan jangkamasa 6:
- $$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \varepsilon_t.$$

Tunjukkan bahawa anggaran kuasa dua terkecil bagi ϕ_1 dan ϕ_2 diberikan oleh:

$$\hat{\phi}_1 = \frac{\hat{\rho}_6(1 - \hat{\rho}_{12})}{1 - \hat{\rho}_6^2} \quad \text{dan} \quad \hat{\phi}_2 = \frac{\hat{\rho}_{12} - \hat{\rho}_6^2}{1 - \hat{\rho}_6^2}$$

[30 markah]

- (b) Tiga set data siri masa telah dikumpul dan akan disuaikan dengan model siri masa. ACF dan PACF bagi tiga siri tersebut diberikan dalam Jadual 1, Jadual 2 dan Jadual 3 di Lampiran A.

- (i) Siri manakah mempamerkan ciri-ciri kebermusiman? Apakah jangkamasa musim bagi siri tersebut
- (ii) Tentukan model yang sesuai bagi setiap siri tersebut. Berikan alasan anda.
- (iii) Hitung anggaran untuk koefisien bagi model dan juga varians bagi ralat yang sepadan.

[30 markah]

- (c) Seorang penyelidik kewangan cuba mendapatkan model yang dapat mencirikan pulangan dan volatiliti indeks saham AS yang sangat berpengaruh. Lampiran B menunjukkan output analisis beliau yang boleh dibahagikan kepada empat peringkat utama.

Bincangkan dapatan analisis disetiap peringkat. Khususnya, bincangkan sebarang bukti bagi kesan tak simetri dan leverage serta bukti untuk menyokong Capital Asset Pricing Model (CAPM).

[40 markah]

Question 4

- (a) Consider the following ARMA(1,2) model for a series with non-zero mean:

$$(1 - \phi B)(Y_t - \mu) = (1 - \theta B^2)\varepsilon_t.$$

- (i) Show that the 1-step and
- m
- step ahead forecasts made at time
- $t = n$
- are given as follows:

$$\begin{aligned}\hat{Y}_n(1) &= \mu(1 - \phi) + \phi Y_n - \theta \varepsilon_{n-1} \\ \hat{Y}_n(m) &= \mu(1 - \phi_1) + \phi_1 \hat{Y}_n(m-1) \quad \text{for } m \geq 3\end{aligned}$$

- (ii) Show that the variance of forecast error for
- $m \geq 3$
- is given by:

$$\text{Var}[\nu_n(m)] = \left[1 + \phi^2 + (\phi^2 - \theta)^2 \left(\frac{1 - \phi_1^{2(m-2)}}{1 - \phi_1^2} \right) \right] \sigma_\varepsilon^2.$$

- (iii) An ARMA(1,2) model was fitted to a time series of length 200 producing the following estimated coefficients:
- $\hat{\phi} = 0.85$
- ,
- $\hat{\theta} = -0.60$
- ,
- $\hat{\mu} = 50$
- ,
- $s_\varepsilon^2 = 4$
- . The latest information available are:
- $Y_{200} = 52$
- ,
- $\hat{\varepsilon}_{200} = -6$
- and
- $\hat{\varepsilon}_{199} = -2$
- .

Calculate forecast values of $\hat{Y}_{200}(m)$ for $m = 1, 2, \dots, 6$ and the corresponding 95% forecast intervals. What is the value for long-term forecast and the corresponding 95% forecast interval? Explain your answer.

- (iv) At time
- $t = 201$
- , a new observation is noted as
- $Y_{201} = 53$
- . Calculate the updated forecasts for
- Y_{202}, \dots, Y_{206}
- . Compare these new forecasts with those calculated in part (iii) above and discuss.

[65 marks]

- (b) A 25 years quarterly data on demand of cotton trousers was collected and fitted to the following SARIMA(0,0,1)(1,0,0) model below:

$$(1 - \phi B^4)(Y_t - \mu) = (1 - \theta B)\varepsilon_t.$$

- (i) Show that the variance of forecast error is given by:

$$\text{Var}[\nu_n(m)] = \left[(1 + \theta^2) \left(\frac{1 - \phi^{2m+2}}{1 - \phi^2} \right) \right] \sigma_\varepsilon^2$$

for $m = 4k + r + 1$ with $1 \leq r < 4$ and $k = 0, 1, 2, \dots$.

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- (ii) Estimated coefficients of the model are found to be $\hat{\phi} = 0.8$, $\hat{\theta} = -0.6$, $\hat{\mu} = 50$, $s_{\varepsilon}^2 = 4$ while recent observations include $Y_{100} = 56$, $Y_{99} = 59$, $Y_{98} = 68$, $Y_{97} = 61$ and $\varepsilon_{100} = 4$. Obtain forecast values of $\hat{Y}_{100}(m)$ for $m = 1, 2, 3, \dots, 16$ and the corresponding 95% forecast intervals.
- (iii) Compare and discuss similarities and differences between the forecast values and the corresponding forecast intervals for a non-seasonal series in (a.iii) with those for a seasonal series in part (b.ii) above.

[35 marks]

Soalan 4

- (a) *Pertimbangkan suatu model ARMA(1,2) yang berikut bagi suatu siri dengan min bukan sifar:*

$$(1 - \phi B)(Y_t - \mu) = (1 - \theta B^2)\varepsilon_t.$$

- (i) *Tunjukkan bahawa telahan 1-langkah dan m-langkah ke hadapan yang dibuat pada $t = n$ diberikan oleh:*

$$\begin{aligned}\hat{Y}_n(1) &= \mu(1 - \phi) + \phi Y_n - \theta \varepsilon_{n-1}, \\ \hat{Y}_n(m) &= \mu(1 - \phi_1) + \phi_1 \hat{Y}_n(m-1) \text{ for } m \geq 3.\end{aligned}$$

- (ii) *Tunjukkan bahawa varians bagi ralat telahan untuk $m \geq 3$ diberikan oleh:*

$$\text{Var}[\nu_n(m)] = \left[1 + \phi^2 + (\phi^2 - \theta)^2 \left(\frac{1 - \phi_1^{2(m-2)}}{1 - \phi_1^2} \right) \right] \sigma_{\varepsilon}^2.$$

- (iii) *Suatu model ARMA(1,2) telah disuaikan kepada suatu siri masa dengan 200 cerapan, menghasilkan nilai anggaran koefisien berikut: $\hat{\phi}_1 = 0.80$, $\hat{\theta}_1 = -0.60$, $\hat{\mu} = 50$, $s_{\varepsilon}^2 = 4$. Maklumat terkini yang ada adalah: $Y_{200} = 52$, $\hat{\varepsilon}_{200} = -6$ and $\hat{\varepsilon}_{199} = -2$.*

Hitung nilai telahan bagi $\hat{Y}_{200}(m)$ untuk $m = 1, 2, \dots, 6$ dan selang telahan 95% yang sepadan. Apakah nilai telahan jangka panjang dan selang telahan 95% yang sepadan? Jelaskan jawapan anda.

- (iv) *Pada waktu $t = 201$ satu cerapan baru dicatat sebagai $Y_{201} = 53$. Hitung telahan kemaskini bagi Y_{202}, \dots, Y_{206} . Bandingkan nilai telahan terbaru ini dengan telahan yang diperolehi dalam bahagian (iii) di atas dan bincangkan.*

[65 markah]

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- (b) *Data sukuan bagi 25 tahun bagi permintaan seluar kapas telah dikumpul dan disesuaikan dengan model SARIMA(0,0,1)(1,0,0) yang berikut:*

$$(1 - \phi B^4)(Y_t - \mu) = (1 - \theta B)\varepsilon_t$$

- (i) *Tunjukkan bahawa varians bagi ralat telahan diberikan oleh:*

$$\text{Var}[v_n(m)] = \left[(1 + \theta^2) \left(\frac{1 - \phi^{2m+2}}{1 - \phi^2} \right) \right] \sigma_\varepsilon^2.$$

untuk $m = 4k + r + 1$ dengan $1 \leq r < 4$ dan $k = 0, 1, 2, \dots$

- (ii) *Anggaran koefisien bagi model didapati adalah $\hat{\phi} = 0.8$, $\hat{\theta} = -0.6$, $\hat{\mu} = 50$, $s_\varepsilon^2 = 4$ sementara cerapan terkini termasuklah $Y_{100} = 56$, $Y_{99} = 59$, $Y_{98} = 68$, $Y_{98} = 61$ and $\varepsilon_{100} = 4$. Dapatkan nilai telahan $\hat{Y}_{100}(m)$ untuk $m = 1, 2, \dots, 16$ dan selang telahan 95% yang sepadan.*
- (iii) *Banding dan bincangkan persamaan dan perbezaan antara nilai telahan dan selang telahan untuk siri tak bermusim di bahagian (a.iii) dengan nilai untuk siri bermusim di bahagian (b.ii) di atas.*

[35 markah]

APPENDIX A/LAMPIRAN ATable 1: Series P, $\hat{\gamma}_0 = 0.117$

Lag	1	2	3	4	5	6	7	8	9
ACF	0.091	-0.054	0.077	-0.017	0.066	0.621	0.034	-0.018	0.091
PACF	0.091	-0.063	0.083	-0.055	0.099	0.603	-0.087	0.079	0.062
Lag	10	11	12	13	14	15	16	17	18
ACF	-0.028	0.026	0.635	0.116	-0.009	0.097	0.016	0.061	0.447
PACF	-0.051	-0.012	0.406	0.093	0.028	-0.114	0.101	0.026	-0.104
Lag	19	20	21	22	23	24	25	26	27
ACF	0.019	-0.052	0.091	-0.037	0.010	0.394	0.121	0.007	0.068
PACF	-0.091	-0.061	-0.061	-0.152	-0.013	0.018	0.097	0.013	0.077

Table 2: Series Q, $\hat{\gamma}_0 = 0.099$

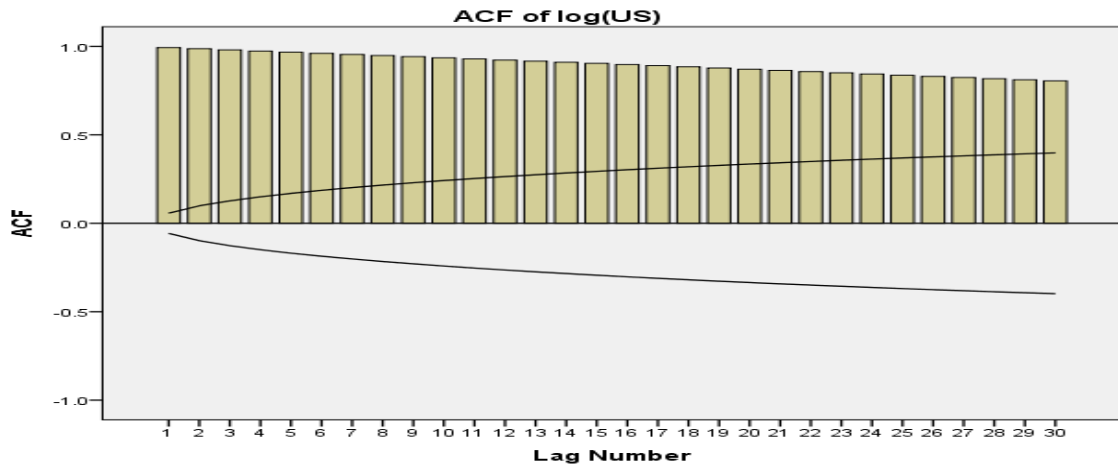
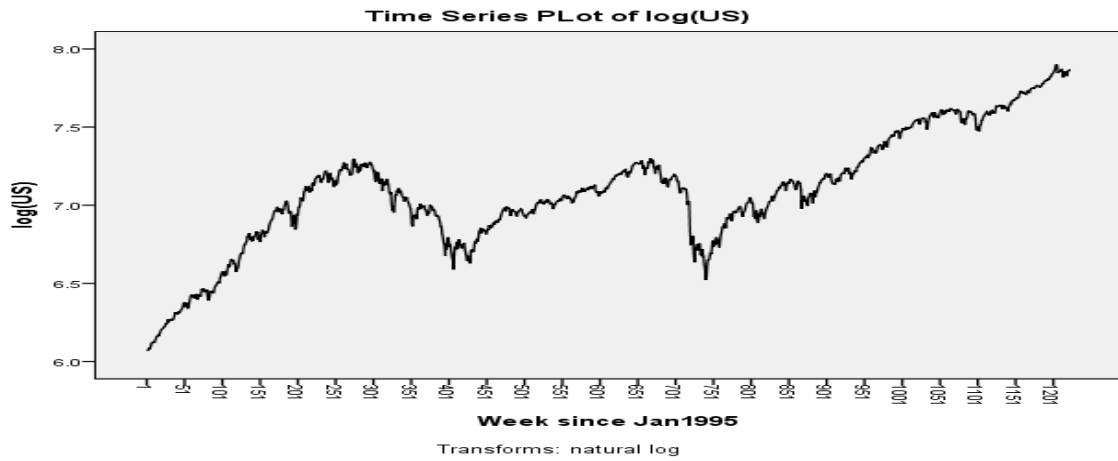
Lag	1	2	3	4	5	6	7	8	9
ACF	0.109	-0.052	0.079	-0.066	0.063	0.484	0.047	0.064	0.089
PACF	0.109	-0.065	0.087	-0.115	0.117	0.447	-0.038	0.128	0.057
Lag	10	11	12	13	14	15	16	17	18
ACF	0.016	-0.055	-0.045	-0.001	0.098	0.030	0.072	0.013	-0.127
PACF	0.090	-0.076	-0.345	0.018	-0.000	-0.124	0.036	0.128	0.198
Lag	19	20	21	22	23	24	25	26	27
ACF	-0.037	0.013	-0.071	0.060	0.039	-0.075	0.061	0.042	-0.052
PACF	-0.065	0.007	0.069	-0.018	-0.116	-0.120	0.089	0.064	-0.033

Table 3: Series R, $\hat{\gamma}_0 = 0.469$

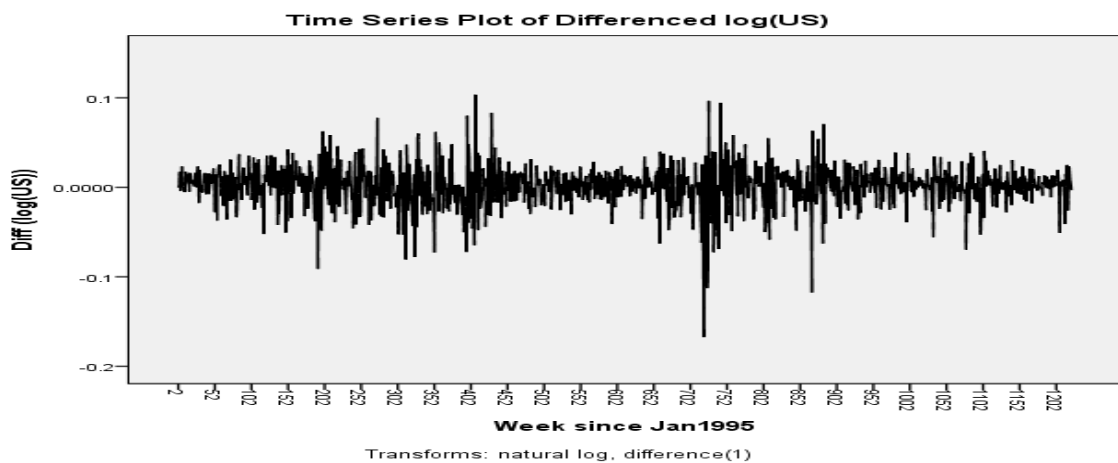
Lag	1	2	3	4	5	6	7	8	9
ACF	0.924	0.804	0.693	0.598	0.524	0.464	0.409	0.367	0.321
PACF	0.924	-0.347	0.104	-0.026	0.072	-0.024	-0.008	0.068	-0.124
Lag	10	11	12	13	14	15	16	17	18
ACF	0.258	0.206	0.175	0.162	0.144	0.113	0.079	0.035	-0.018
PACF	-0.080	0.085	0.065	0.018	-0.097	-0.049	0.017	-0.149	-0.016
Lag	19	20	21	22	23	24	25	26	27
ACF	-0.057	-0.070	-0.062	-0.035	-0.004	0.025	0.060	0.085	0.102
PACF	0.070	0.088	0.004	0.080	0.063	0.028	0.065	-0.052	0.046

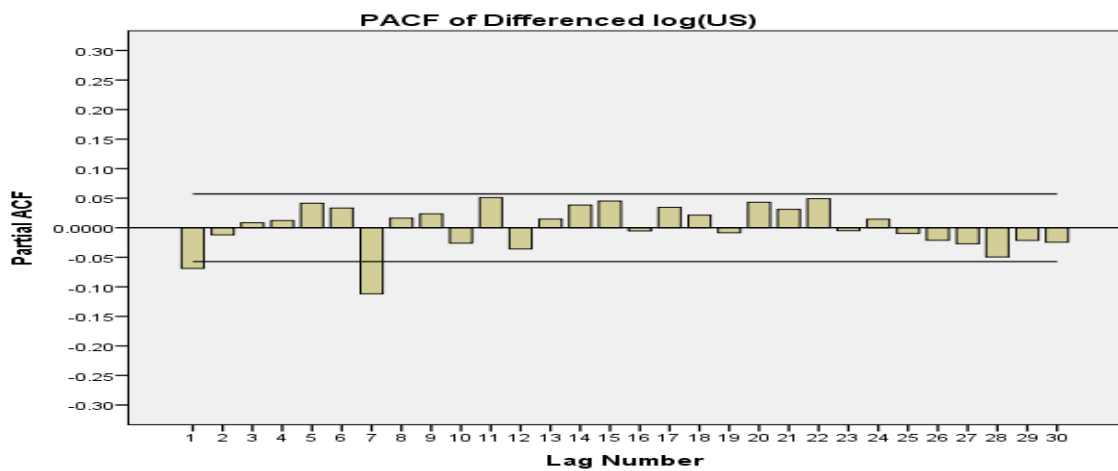
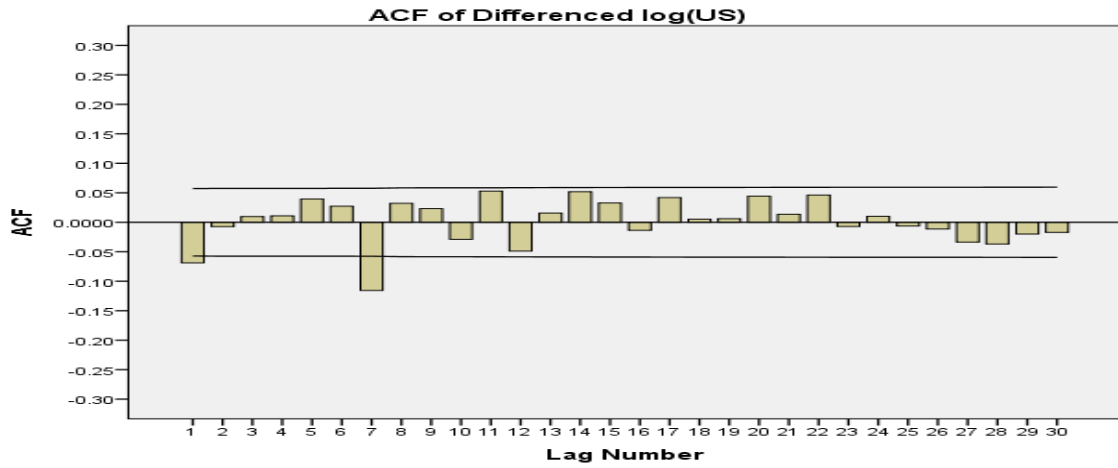
APPENDIX B/LAMPIRAN B

Step 1a



Step 1b





Step 2a

Dependent Variable: D(LUS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(1)	-0.064369	0.028571	-2.252983	0.0244
Adjusted R-squared	0.000010	S.D. dependent var		0.022799
S.E. of regression	0.022799	Akaike info criterion		-4.723382
Log likelihood	2884.625	Schwarz criterion		-4.719199

Dependent Variable: D(LUS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
MA(1)	-0.064858	0.028558	-2.271077	0.0233
Adjusted R-squared	0.000052	S.D. dependent var		0.022790
S.E. of regression	0.022789	Akaike info criterion		-4.724238
Log likelihood	2887.509	Schwarz criterion		-4.720057

Step 2b

ACF, PACF and LB stats from MA(1)

	AC	PAC	Q-Stat	Prob
1	-0.005	-0.005	0.0271	
2	-0.007	-0.007	0.0868	0.768
3	0.010	0.010	0.2148	0.898
4	0.014	0.014	0.4681	0.926
5	0.042	0.042	2.6243	0.623
6	0.023	0.023	3.2570	0.660
9	0.023	0.021	20.371	0.009
12	-0.045	-0.038	26.485	0.005
18	0.009	0.019	34.546	0.007
24	0.010	0.014	40.709	0.013
36	0.022	0.014	50.800	0.041

Breusch-Godfrey LM Test Lag 3 on MA(1)

Obs*R-squared	0.000000	Prob. Chi-Square(3)	1.0000
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ARCH-LM Test Lag 3 on MA(1)

Obs*R-squared	75.36475	Prob. Chi-Square(3)	0.0000
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ARCH-LM Test Lag 6 on MA(1)

Obs*R-squared	120.5620	Prob. Chi-Square(6)	0.0000
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Step 3a

Dependent Variable: D(LUS)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.076274	0.032801	-2.325358	0.0201
Variance Equation				
C	1.74E-05	3.96E-06	4.402427	0.0000
RESID(-1)^2	0.131013	0.013125	9.981674	0.0000
GARCH(-1)	0.841878	0.018825	44.72100	0.0000
Adjusted R-squared	-0.000080	S.D. dependent var		0.022790
S.E. of regression	0.022791	Akaike info criterion		-4.930221
Log likelihood	3016.365	Schwarz criterion		-4.913500

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Step 3b

ACF, PACF and LB stats from MA(1)-G(1,1)

	AC	PAC	Q-Stat	Prob*
1	0.020	0.020	0.4818	
2	0.033	0.033	1.8132	0.178
3	0.009	0.008	1.9121	0.384
4	0.035	0.034	3.4574	0.326
5	-0.005	-0.007	3.4881	0.480
6	-0.011	-0.013	3.6437	0.602
9	0.015	0.016	7.3250	0.502
12	-0.016	-0.022	10.440	0.491
18	0.004	0.002	19.769	0.286
24	0.043	0.038	31.426	0.113
36	0.031	0.030	40.958	0.225

ARCH-LM Test Lag 3 on MA(1)-G(1,1)

Obs*R-squared	3.046513	Prob. Chi-Square(3)	0.3845
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ARCH-LM Test Lag 6 on MA(1)-G(1,1)

Obs*R-squared	3.917941	Prob. Chi-Square(6)	0.6878
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Step 3c

Dependent Variable: D(LUS)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.081615	0.032967	-2.475640	0.0133
MA(2)	0.036368	0.031083	1.170027	0.2420
Variance Equation				
C	1.72E-05	3.92E-06	4.384355	0.0000
RESID(-1)^2	0.131531	0.013351	9.851966	0.0000
GARCH(-1)	0.842043	0.018750	44.90902	0.0000
Adjusted R-squared	-0.002400	S.D. dependent var	0.022790	
S.E. of regression	0.022817	Akaike info criterion	-4.929797	
Log likelihood	3017.106	Schwarz criterion	-4.908896	

Dependent Variable: D(LUS)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.415572	0.321328	-1.293297	0.1959
MA(1)	0.337771	0.335319	1.007311	0.3138
Variance Equation				
C	1.69E-05	3.91E-06	4.332239	0.0000
RESID(-1)^2	0.130957	0.013186	9.931181	0.0000
GARCH(-1)	0.843108	0.018584	45.36721	0.0000
Adjusted R-squared	-0.002420	S.D. dependent var	0.022799	
S.E. of regression	0.022827	Akaike info criterion	-4.927433	
Log likelihood	3013.198	Schwarz criterion	-4.906518	

Dependent Variable: D(LUS)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.074879	0.034136	-2.193543	0.0283
Variance Equation				
C	1.58E-05	3.69E-06	4.275102	0.0000
RESID(-1)^2	0.150724	0.024913	6.049993	0.0000
RESID(-2)^2	-0.030317	0.025095	-1.208068	0.2270
GARCH(-1)	0.854969	0.018408	46.44679	0.0000
Adjusted R-squared	-0.000049	S.D. dependent var	0.022790	
S.E. of regression	0.022790	Akaike info criterion	-4.928977	
Log likelihood	3016.605	Schwarz criterion	-4.908075	

Dependent Variable: D(LUS)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.076161	0.034813	-2.187748	0.0287
Variance Equation				
C	2.23E-05	5.19E-06	4.298795	0.0000
RESID(-1)^2	0.171777	0.016325	10.52207	0.0000
GARCH(-1)	0.344172	0.120303	2.860862	0.0042
GARCH(-2)	0.448811	0.114569	3.917383	0.0001
Adjusted R-squared	-0.000077	S.D. dependent var	0.022790	
S.E. of regression	0.022791	Akaike info criterion	-4.930527	
Log likelihood	3017.552	Schwarz criterion	-4.909626	

Step 4

Dependent Variable: D(LUS)

$$\text{LOG(GARCH)} = \text{C(2)} + \text{C(3)} * \text{ABS(RESID(-1)/@SQRT(GARCH(-1)))} \\ + \text{C(4)} * \text{RESID(-1)/@SQRT(GARCH(-1))} + \text{C(5)} * \text{LOG(GARCH(-1))}$$

Variable	Coefficient	Std. Error	z-Statistic	Prob.
MA(1)	-0.055449	0.032342	-1.714439	0.0864
Variance Equation				
C(2)	-0.801554	0.096214	-8.330938	0.0000
C(3)	0.179838	0.028423	6.327247	0.0000
C(4)	-0.188880	0.016076	-11.74892	0.0000
C(5)	0.913515	0.010946	83.45295	0.0000
Adjusted R-squared	-0.000037	S.D. dependent var		0.022790
S.E. of regression	0.022790	Akaike info criterion		-5.002212
Log likelihood	3061.351	Schwarz criterion		-4.981311

Dependent Variable: D(LUS)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
@SQRT(GARCH)	0.140834	0.026230	5.369162	0.0000
MA(1)	-0.108559	0.034870	-3.113264	0.0019
Variance Equation				
C	2.02E-05	4.11E-06	4.911508	0.0000
RESID(-1)^2	0.153645	0.015209	10.10205	0.0000
GARCH(-1)	0.816431	0.020405	40.01155	0.0000
Adjusted R-squared	-0.004025	S.D. dependent var		0.022790
S.E. of regression	0.022836	Akaike info criterion		-4.954550
Log likelihood	3032.230	Schwarz criterion		-4.933649

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