Supplementary Material

Contents

Note: All ARIMA models were constructed by R version 4.1.0

1 Predict the total ASIR based on ARIMA model

1.1 Total ASIR time-series plot

The total ASIR trend from 1990 to 2021 was showed in figure 1-1.

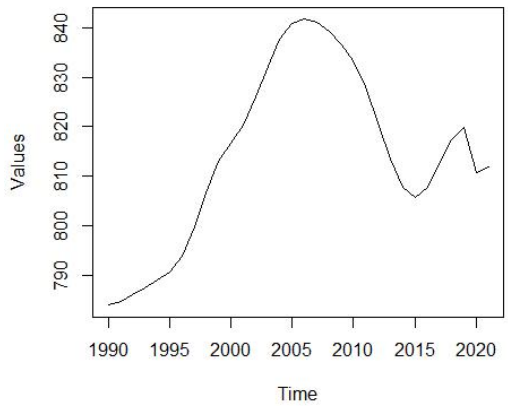

Figure 1-1 Total ASIR time-series trend plot

1.2 Difference of time-series

Figure 1-2 showed the first order difference of total ASIR time-series. Obviously, it was not stationary. After performing the second order difference (Figure 1-3), we found that the time-series was stationary (Figure 1-4, *adf.test*).

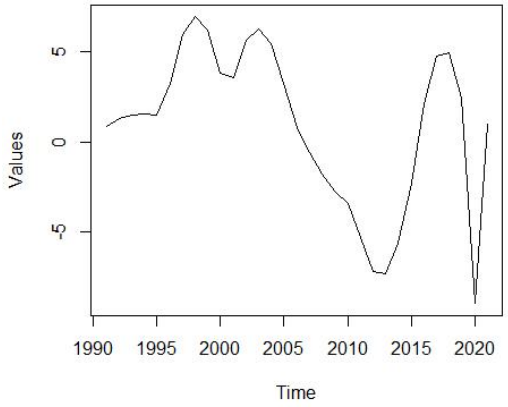

Figure 1-2 The first order difference of total ASIR time-series

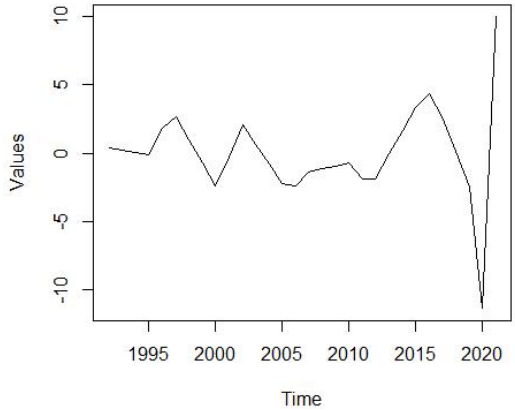

Figure 1-3 The second order difference of total ASIR time-series

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag   ADF p.value
[1,]   0 -4.92    0.01
[2,]   1 -3.27    0.01
[3,]   2 -4.21    0.01
[4,]   3 -3.00    0.01
Type 2: with drift no trend
     lag   ADF p.value
[1,]   0 -4.81  0.0100
[2,]   1 -3.21  0.0331
[3,]   2 -4.12  0.0100
[4,]   3 -2.93  0.0570
Type 3: with drift and trend
     lag   ADF p.value
[1,]   0 -4.61  0.0100
[2,]   1 -3.14  0.1330
[3,]   2 -4.03  0.0212
[4,]   3 -2.86  0.2352
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 1-4 Time-series stationarity test after the second order difference

1.3 White noise test and draw ACF and PACF plots

We used “Box-Ljung” method to perform white noise test. White noise test results shwed *P* values were 0.9214 for “lag=6” and 0.9926 for “lag=12” (Figure 1-5). We drew ACF and PACF plots for stationary time-series (Figure 1-6 and Figure 1-7).

```
> Box.test(values_diff,lag=6,type='Ljung-Box')

        Box-Ljung test

data:  values_diff
X-squared = 1.9811, df = 6, p-value = 0.9214

> Box.test(values_diff,lag=12,type='Ljung-Box')

        Box-Ljung test

data:  values_diff
X-squared = 3.3432, df = 12, p-value = 0.9926
```

Figure 1-5 White noise test for stationary time-series

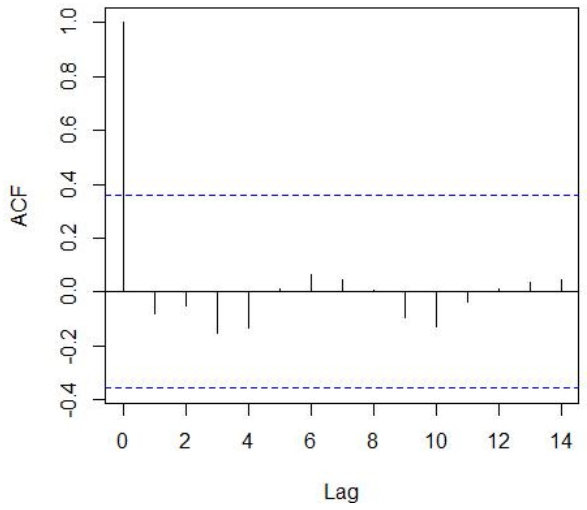

Figure 1-6 ACF plot for stationary time-series

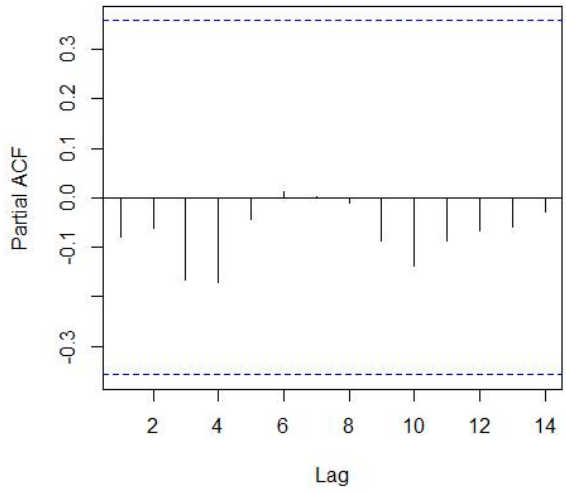

Figure 1-7 PACF plot for stationary time-series

1.4 ARIMA model constructing

In the section 1.3, we found that the stationary time-series may be a white noise sequence. In theory, the white noise sequence may not be suitable for fitting models. However, due to the actual data are complex and various, it's very difficult to ensure that all the data used for modeling is perfect and flawless. Therefore, we still considered using these data to construct ARIMA models for prediction. We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 1-1.

Table 1-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	160.0562	162.8586
ARIMA(1,2,1)	159.5873	163.7909
ARIMA(1,2,2)	161.5301	167.1349
ARIMA(2,2,0)	161.9855	166.1891
ARIMA(2,2,1)	161.5195	167.1243
ARIMA(2,2,2)	-	-

From table 1-1, we observed that there was lower AIC and BIC in ARIMA(1,2,1) model. Therefore, we chose ARIMA(1,2,1) model to fit the total ASIR data.

1.5 White noise test for residual

From figure 1-8, we found that residuals were white noise sequence (All P>0.05, Bottom Left). Therefore, the ARIMA(1,2,1) model was successful and reliable.

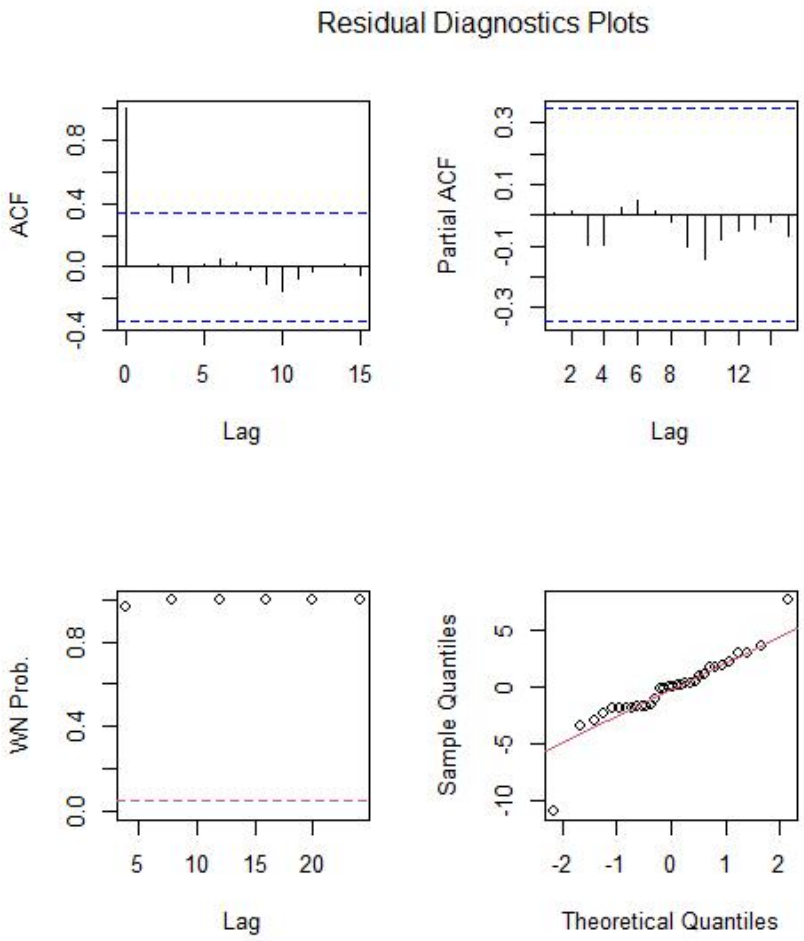

Figure 1-8 ARIMA(1,2,1) model test

2 Predict the male ASIR based on ARIMA model

2.1 Male ASIR time-series plot

The male ASIR trend from 1990 to 2021 was showed in figure 2-1.

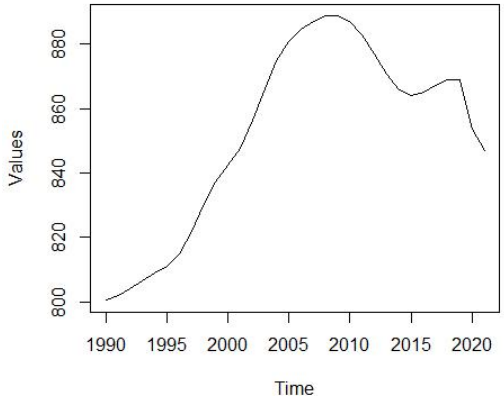

Figure 2-1 Male ASIR time-series trend plot

2.2 Difference of time-series

Figure 2-2 showed the first order difference of male ASIR time-series. Obviously, it was not stationary. After performing the second order difference (Figure 2-3), we found that the time-series was stationary (Figure 2-4, *adf.test*).

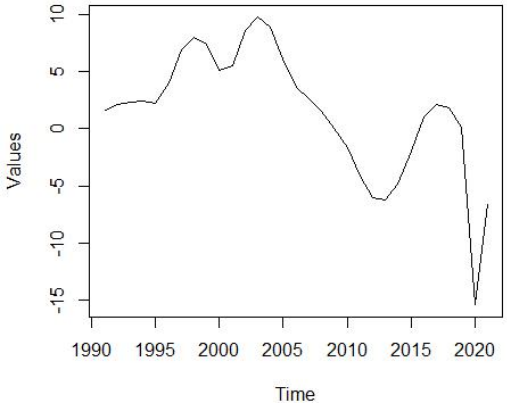

Figure 2-2 The first order difference of male ASIR time-series

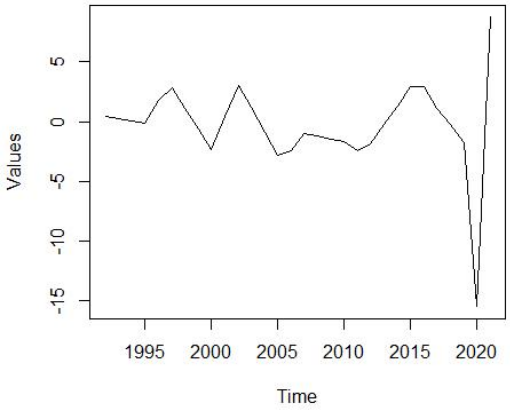

Figure 2-3 The second order difference of male ASIR time-series

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag   ADF p.value
[1,]   0 -5.64  0.0100
[2,]   1 -2.58  0.0125
[3,]   2 -3.25  0.0100
[4,]   3 -2.61  0.0112
Type 2: with drift no trend
     lag   ADF p.value
[1,]   0 -5.59  0.0100
[2,]   1 -2.57  0.1233
[3,]   2 -3.26  0.0292
[4,]   3 -2.62  0.1033
Type 3: with drift and trend
     lag   ADF p.value
[1,]   0 -5.61  0.0100
[2,]   1 -2.67  0.3060
[3,]   2 -3.47  0.0655
[4,]   3 -2.87  0.2339
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 2-4 Time-series stationarity test after the second order difference

2.3 White noise test and draw ACF and PACF plots

We used “Box-Ljung” method to perform white noise test. White noise test results shwed *P* values were 0.9388 for “lag=6” and 0.9994 for “lag=12” (Figure 2-5). We drew ACF and PACF plots for stationary time-series (Figure 2-6 and Figure 2-7).

```
> Box.test(Values_diff,lag=6,type='Ljung-Box')

        Box-Ljung test

data:  Values_diff
X-squared = 1.7792, df = 6, p-value = 0.9388

> Box.test(Values_diff,lag=12,type='Ljung-Box')

        Box-Ljung test

data:  Values_diff
X-squared = 1.978, df = 12, p-value = 0.9994
```

Figure 2-5 White noise test for stationary time-series

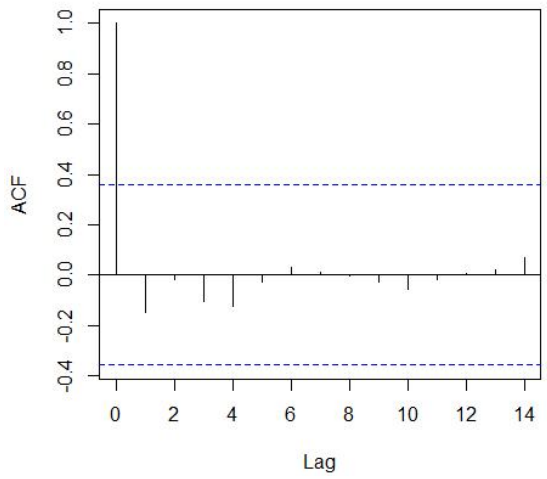

Figure 2-6 ACF plot for stationary time-series

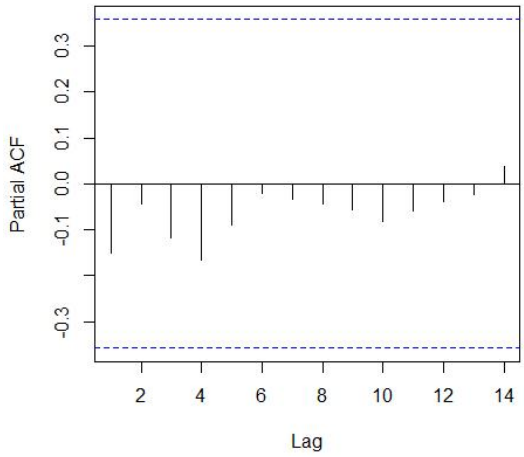

Figure 2-7 PACF plot for stationary time-series

2.4 ARIMA model constructing

We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 2-1.

Table 2-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	166.3027	169.1051
ARIMA(1,2,1)	167.4590	171.6626
ARIMA(1,2,2)	169.4553	175.0601
ARIMA(2,2,0)	168.2750	172.4786
ARIMA(2,2,1)	-	-
ARIMA(2,2,2)	171.3930	178.3990

From table 2-1, we observed that there was lower AIC and BIC in ARIMA(1,2,0) model. Therefore, we chose ARIMA(1,2,0) model to fit the male ASIR data.

2.5 White noise test for residual

From figure 2-8, we found that residuals were white noise sequence (All $P>0.05$, Bottom Left). Therefore, the ARIMA(1,2,0) model was successful and reliable.

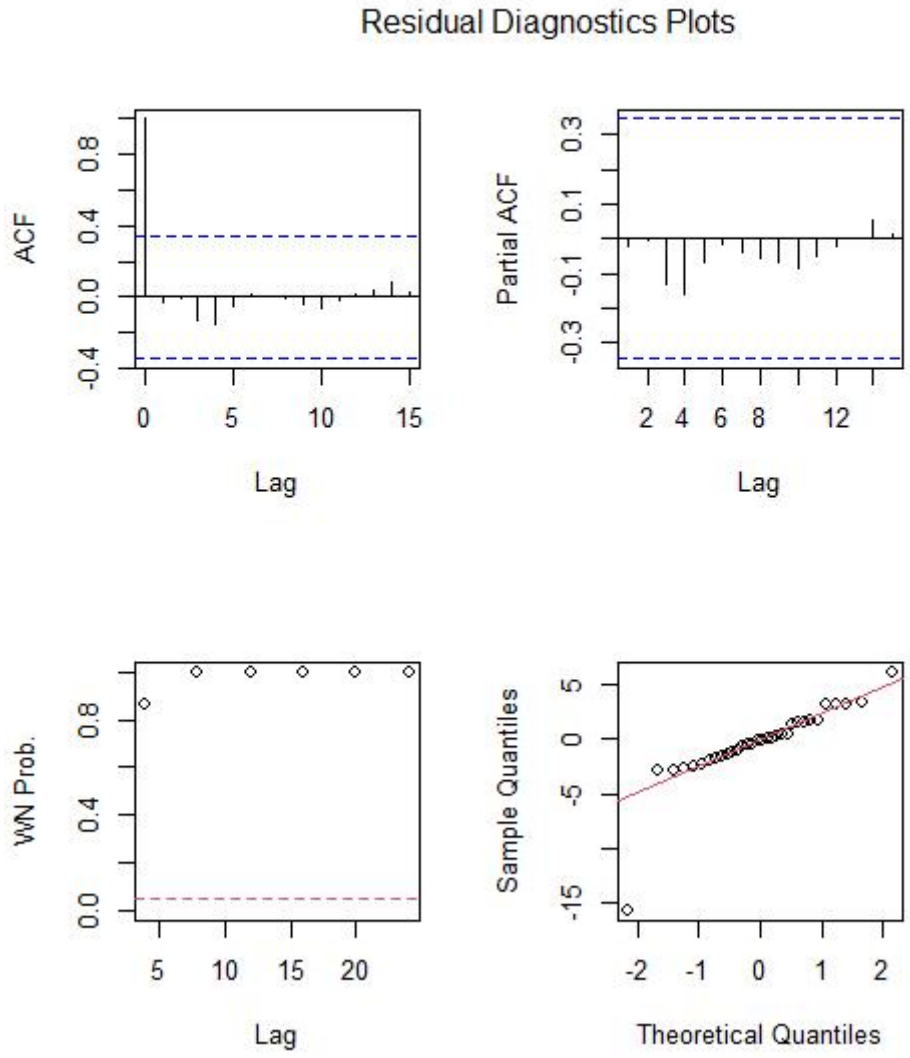

Figure 2-8 ARIMA(1,2,0) model test

3 Predict the female ASIR based on ARIMA model

3.1 Female ASIR time-series plot

The female ASIR trend from 1990 to 2021 was showed in figure 3-1.

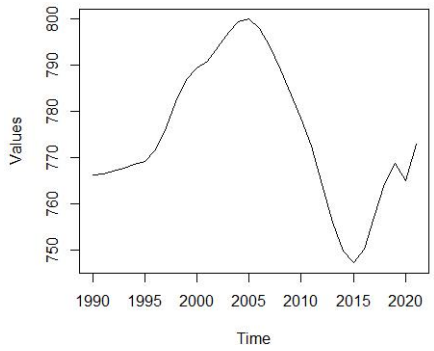

Figure 3-1 Female ASIR time-series trend plot

3.2 Difference of time-series

Figure 3-2 showed the first order difference of female ASIR time-series. Obviously, it was not stationary. After performing the second order difference (Figure 3-3), we found that the time-series was stationary (Figure 3-4, *adf.test*).

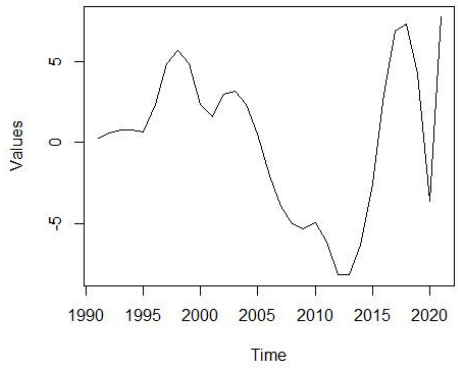

Figure 3-2 The first order difference of female ASIR time-series

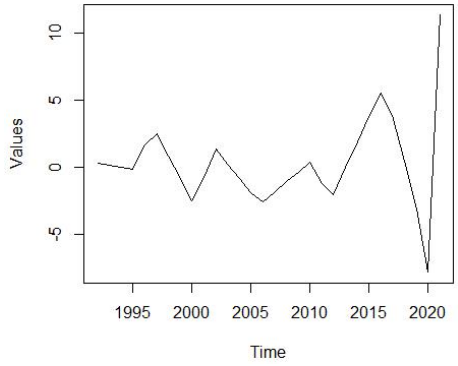

Figure 3-3 The second order difference of female ASIR time-series

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag   ADF p.value
[1,]   0 -3.81  0.0100
[2,]   1 -3.76  0.0100
[3,]   2 -3.25  0.0100
[4,]   3 -1.87  0.0614
Type 2: with drift no trend
     lag   ADF p.value
[1,]   0 -3.73  0.0100
[2,]   1 -3.73  0.0100
[3,]   2 -3.23  0.0313
[4,]   3 -1.86  0.3795
Type 3: with drift and trend
     lag   ADF p.value
[1,]   0 -3.62  0.0471
[2,]   1 -3.88  0.0282
[3,]   2 -3.41  0.0742
[4,]   3 -2.07  0.5302
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 3-4 Time-series stationarity test after the second order difference

3.3 White noise test and draw ACF and PACF plots

We used “Box-Ljung” method to perform white noise test. White noise test results shwed *P* values were 0.8461 for “lag=6” and 0.9024 for “lag=12” (Figure 3-5). We drew ACF and PACF plots for stationary time-series (Figure 3-6 and Figure 3-7).

```
> Box.test(Values_diff,lag=6,type='Ljung-Box'

        Box-Ljung test

data:  Values_diff
X-squared = 2.6943, df = 6, p-value = 0.8461

> Box.test(Values_diff,lag=12,type='Ljung-Box

        Box-Ljung test

data:  Values_diff
X-squared = 6.26, df = 12, p-value = 0.9024
```

Figure 3-5 White noise test for stationary time-series

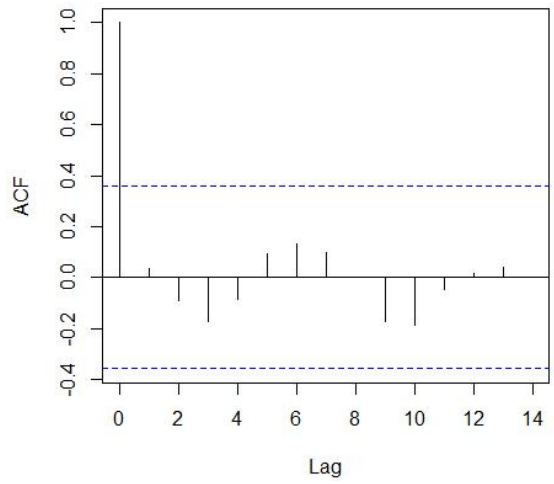

Figure 3-6 ACF plot for stationary time-series

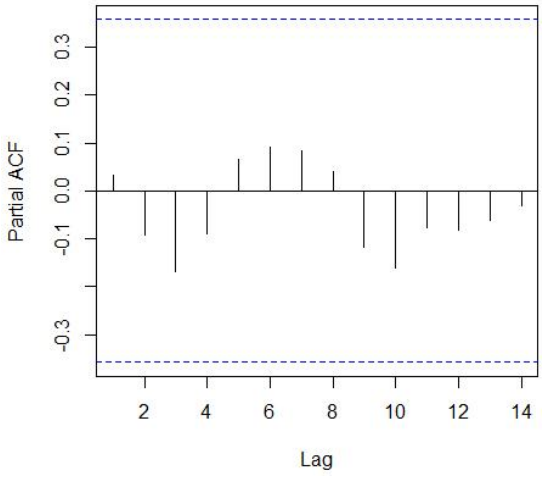

Figure 3-7 PACF plot for stationary time-series

3.4 ARIMA model constructing

We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 3-1.

Table 3-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	158.5276	161.3300
ARIMA(1,2,1)	160.4107	164.6143
ARIMA(1,2,2)	161.5719	167.1767
ARIMA(2,2,0)	159.3101	163.5137
ARIMA(2,2,1)	161.0241	166.6289
ARIMA(2,2,2)	159.9508	166.9568

From table 3-1, we observed that there was lower AIC and BIC in ARIMA(1,2,0) model. Therefore, we chose ARIMA(1,2,0) model to fit the female ASIR data.

3.5 White noise test for residual

From figure 3-8, we found that residuals were white noise sequence (All P>0.05, Bottom Left). Therefore, the ARIMA(1,2,0) model was successful and reliable.

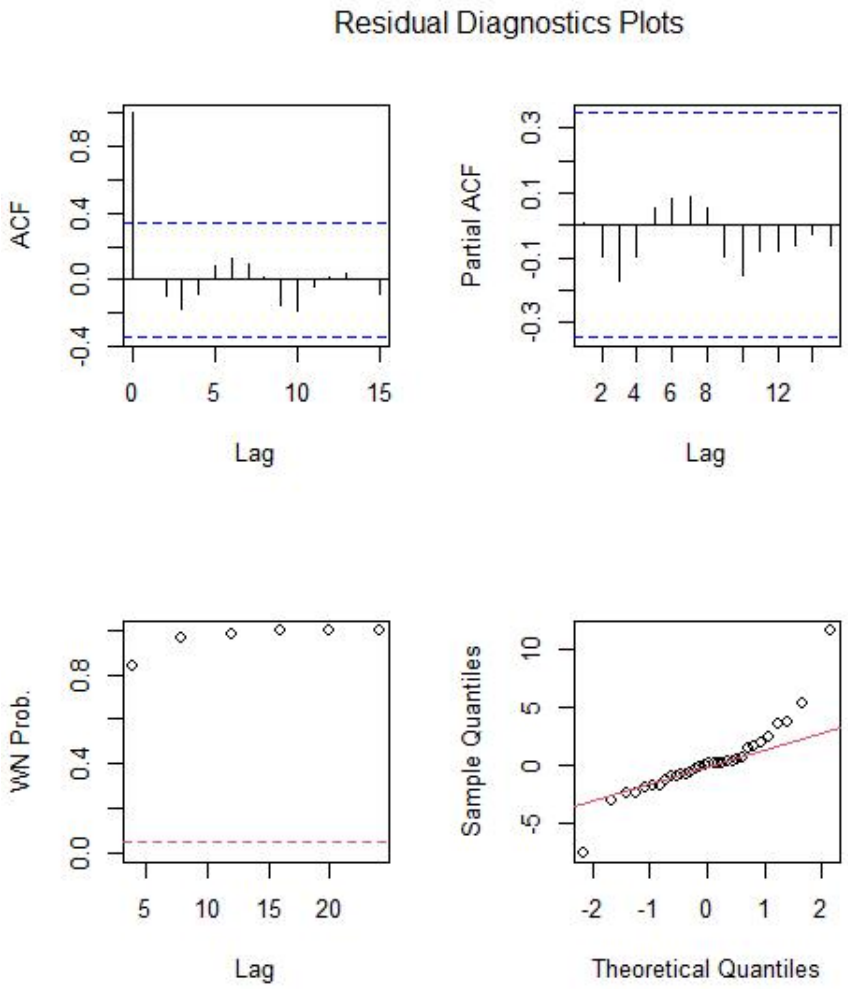

Figure 3-8 ARIMA(1,2,0) model test

4 Predict the total ASPR based on ARIMA model

4.1 Total ASPR time-series plot

The total ASPR trend from 1990 to 2021 was showed in figure 4-1.

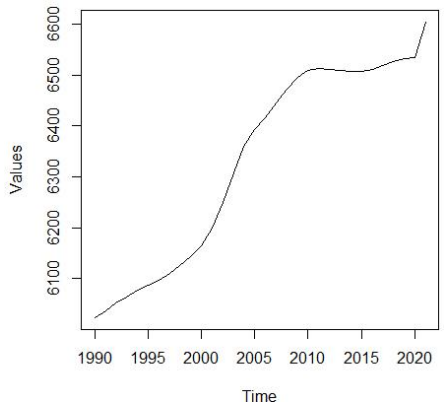

Figure 4-1 Total ASPR time-series trend plot

4.2 Difference of time-series

Figure 4-2 showed the first order difference of total ASPR time-series. Obviously, it was not stationary. After performing the second order difference (Figure 4-3), we found that the time-series was not still stationary (Figure 4-4, *adf.test*). Actual data are often complex and various. Therefore, we selected optimal ARIMA parameters (p, d, q) based on AIC and BIC.

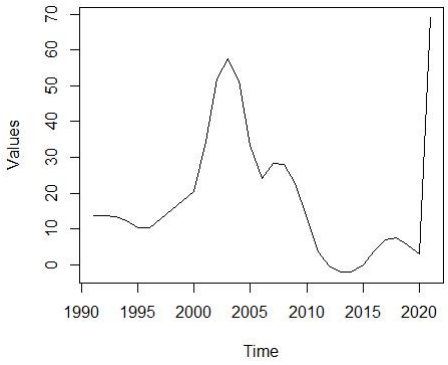

Figure 4-2 The first order difference of total ASPR time-series

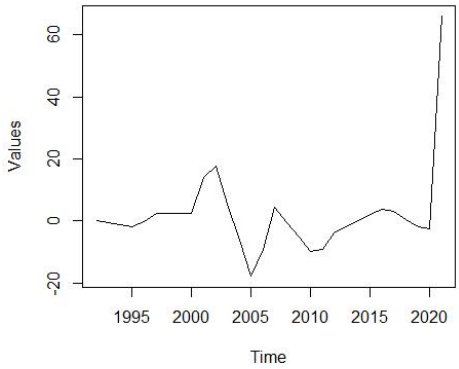

Figure 4-3 The second order difference of total ASPR time-series

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag    ADF p.value
[1,]   0 -1.317  0.2009
[2,]   1 -1.744  0.0795
[3,]   2 -0.885  0.3539
[4,]   3 -0.576  0.4635
Type 2: with drift no trend
     lag    ADF p.value
[1,]   0 -1.262   0.594
[2,]   1 -1.686   0.445
[3,]   2 -0.823   0.746
[4,]   3 -0.510   0.854
Type 3: with drift and trend
     lag    ADF p.value
[1,]   0 -1.048   0.915
[2,]   1 -1.460   0.775
[3,]   2 -0.493   0.976
[4,]   3 -0.103   0.990
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 4-4 Time-series stationarity test after the second order difference

4.3 White noise test and draw ACF and PACF plots

We used "Box-Ljung" method to perform white noise test. White noise test results shwed *P* values were 0.9903 for "lag=6" and 0.9810 for "lag=12" (Figure 4-5). We drew ACF and PACF plots for time-series (Figure 4-6 and Figure 4-7).

```
> Box.test(values_diff,lag=6,type='Ljung-Box')

        Box-Ljung test

data:  values_diff
X-squared = 0.86063, df = 6, p-value = 0.9903

> Box.test(values_diff,lag=12,type='Ljung-Box')

        Box-Ljung test

data:  values_diff
X-squared = 4.1305, df = 12, p-value = 0.981
```

Figure 4-5 White noise test for time-series

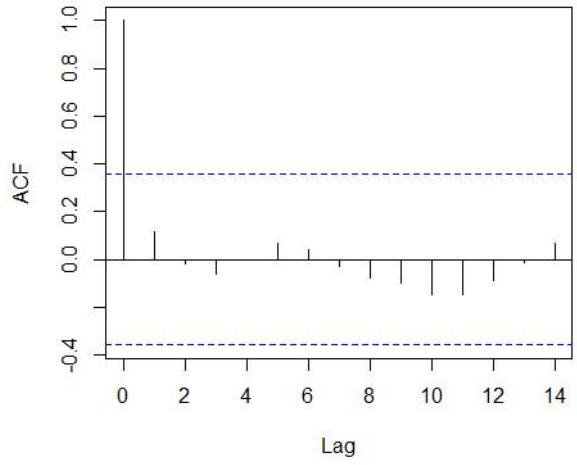

Figure 4-6 ACF plot for time-series

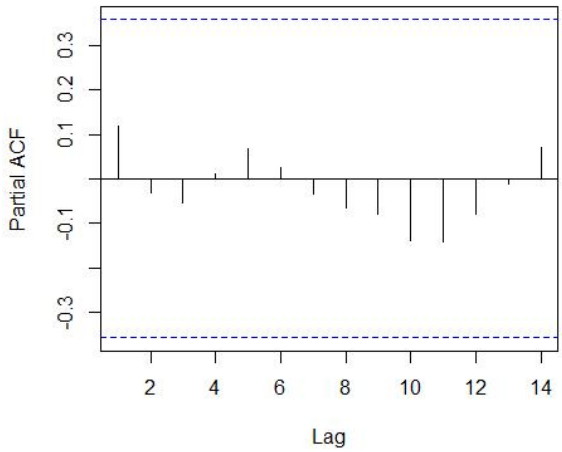

Figure 4-7 PACF plot for time-series

4.4 ARIMA model constructing

We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 4-1.

Table 4-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	244.7780	247.5804
ARIMA(1,2,1)	245.8039	250.0075
ARIMA(1,2,2)	247.7949	253.3997
ARIMA(2,2,0)	245.5806	249.7842
ARIMA(2,2,1)	247.5281	253.1329
ARIMA(2,2,2)	249.4055	256.4115

From table 4-1, we observed that there was lower AIC and BIC in ARIMA(1,2,0) model. Therefore, we chose ARIMA(1,2,0) model to fit the total ASPR data.

4.5 White noise test for residual

From figure 4-8, we found that residuals were white noise sequence (All P>0.05, Bottom Left). Therefore, the ARIMA(1,2,0) model was successful and reliable.

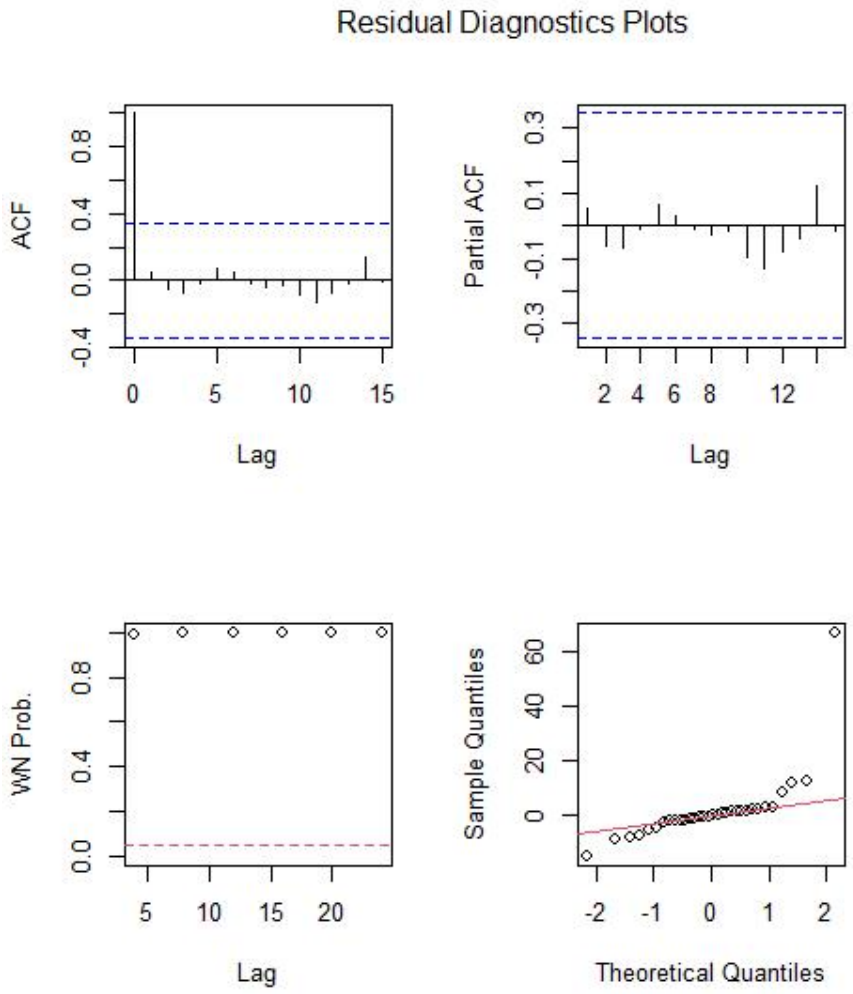

Figure 4-8 ARIMA(1,2,0) model test

5 Predict the male ASPR based on ARIMA model

5.1 Male ASPR time-series plot

The male ASPR trend from 1990 to 2021 was showed in figure 5-1.

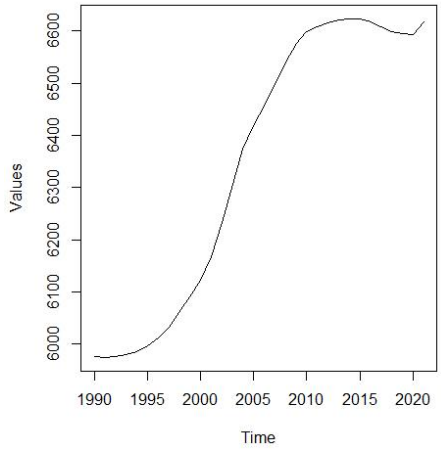

Figure 5-1 Male ASPR time-series trend plot

5.2 Difference of time-series

Figure 5-2 showed the first order difference of male ASPR time-series. Obviously, it was not stationary. After performing the second order difference (Figure 5-3), we found that the time-series was not still stationary (Figure 5-4, *adf.test*). We selected optimal ARIMA parameters (p, d, q) based on AIC and BIC.

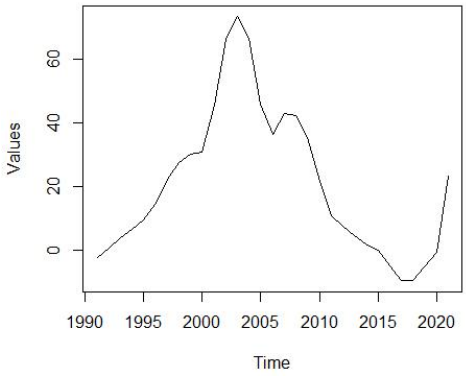

Figure 5-2 The first order difference of male ASPR time-series

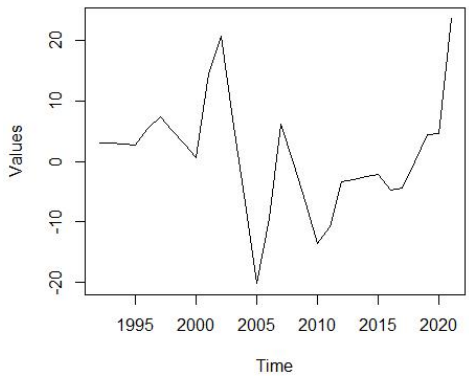

Figure 5-3 The second order difference of male ASPR time-series

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag   ADF p.value
[1,]   0 -1.89  0.0584
[2,]   1 -3.04  0.0100
[3,]   2 -1.50  0.1364
[4,]   3 -1.10  0.2779
Type 2: with drift no trend
     lag   ADF p.value
[1,]   0 -1.87  0.3774
[2,]   1 -2.99  0.0495
[3,]   2 -1.46  0.5270
[4,]   3 -1.05  0.6663
Type 3: with drift and trend
     lag    ADF p.value
[1,]   0 -1.575   0.728
[2,]   1 -2.714   0.290
[3,]   2 -0.872   0.942
[4,]   3 -0.254   0.986
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 5-4 Time-series stationarity test after the second order difference

5.3 White noise test and draw ACF and PACF plots

We used “Box-Ljung” method to perform white noise test. White noise test results shwed *P* values were 0.0204 for “lag=6” and 0.0152 for “lag=12” (Figure 5-5). We drew ACF and PACF plots for time-series (Figure 5-6 and Figure 5-7).

```
> Box.test(values_diff,lag=6,type='Ljung-Box')

        Box-Ljung test

data:  values_diff
X-squared = 14.978, df = 6, p-value = 0.02043

> Box.test(values_diff,lag=12,type='Ljung-Box')

        Box-Ljung test

data:  values_diff
X-squared = 24.927, df = 12, p-value = 0.01517
```

Figure 5-5 White noise test for time-series

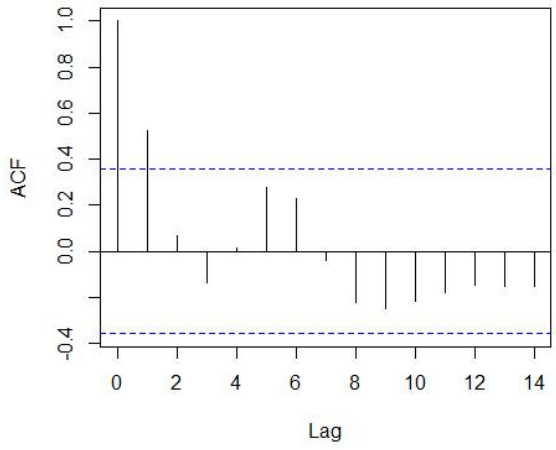

Figure 5-6 ACF plot for time-series

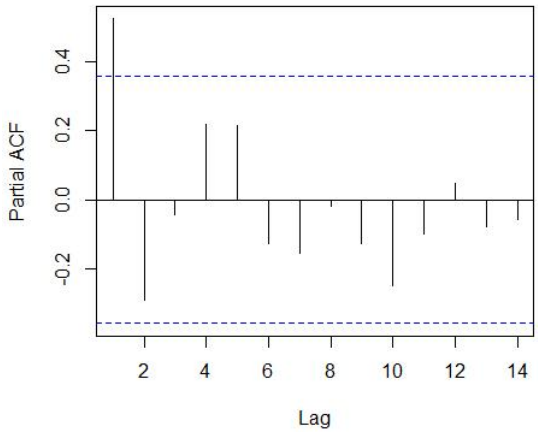

Figure 5-7 PACF plot for time-series

5.4 ARIMA model constructing

We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 5-1.

Table 5-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	208.8581	211.6605
ARIMA(1,2,1)	202.3354	206.5390
ARIMA(1,2,2)	204.2162	209.8210
ARIMA(2,2,0)	204.1165	208.3200
ARIMA(2,2,1)	204.1129	209.7177
ARIMA(2,2,2)	206.0342	213.0402

From table 5-1, we observed that there was lower AIC and BIC in ARIMA(1,2,1) model. Therefore, we chose ARIMA(1,2,1) model to fit the male ASPR data.

5.5 White noise test for residual

From figure 5-8, we found that residuals were white noise sequence (All $P>0.05$, Bottom Left). Therefore, the ARIMA(1,2,1) model was successful and reliable.

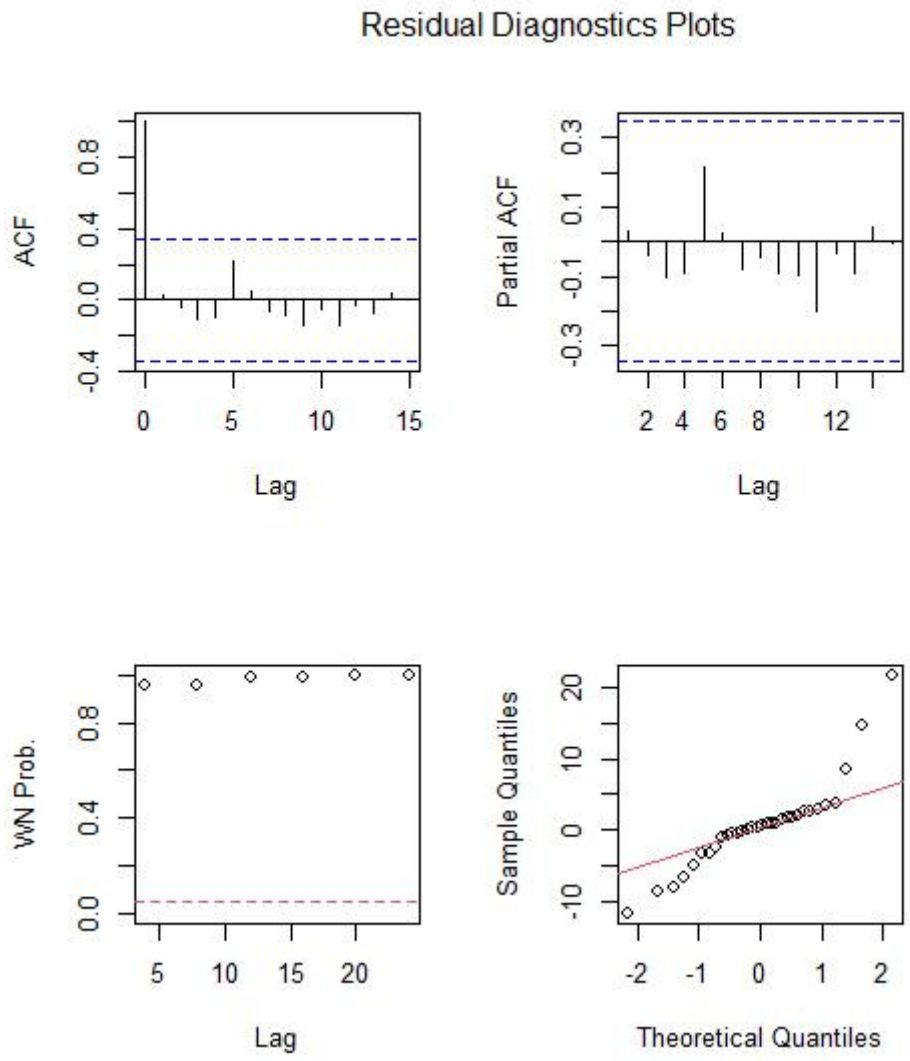

Figure 5-8 ARIMA(1,2,1) model test

6 Predict the female ASPR based on ARIMA model

6.1 Female ASPR time-series plot

The female ASPR trend from 1990 to 2021 was showed in figure 6-1.

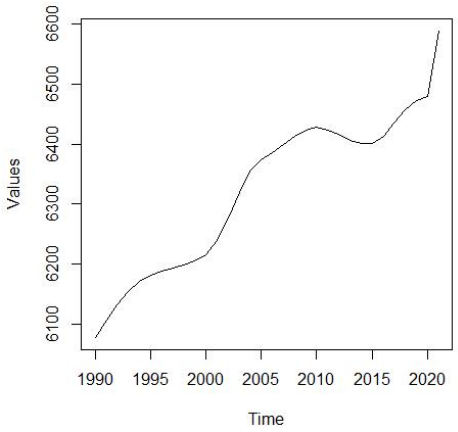

Figure 6-1 Female ASPR time-series trend plot

6.2 Difference of time-series

Figure 6-2 showed the first order difference of female ASPR time-series. Obviously, it was not stationary. After performing the second order difference (Figure 6-3), we found that the time-series was not still stationary (Figure 6-4, *adf.test*). We selected optimal ARIMA parameters (p, d, q) based on AIC and BIC.

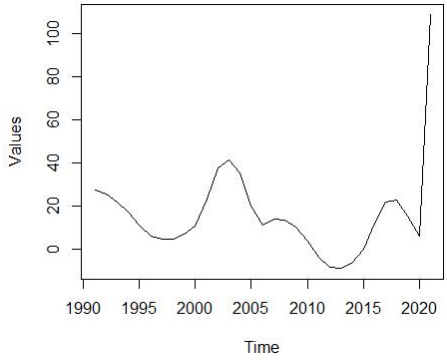

Figure 6-2 The first order difference of female ASPR time-series

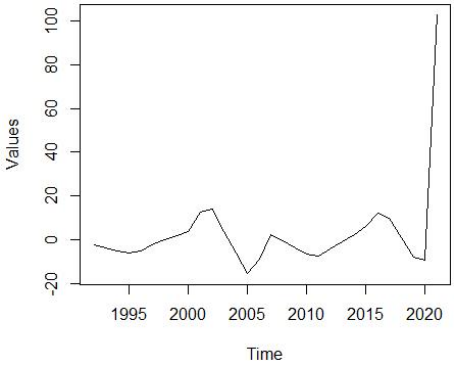

Figure 6-3 The second order difference of female ASPR time-series

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag    ADF p.value
[1,]   0 -1.815  0.0693
[2,]   1 -2.159  0.0331
[3,]   2 -0.732  0.4083
[4,]   3 -0.221  0.5726
Type 2: with drift no trend
     lag    ADF p.value
[1,]   0 -1.711   0.435
[2,]   1 -2.066   0.306
[3,]   2 -0.655   0.804
[4,]   3 -0.139   0.932
Type 3: with drift and trend
     lag    ADF p.value
[1,]   0 -1.870   0.610
[2,]   1 -2.373   0.415
[3,]   2 -0.980   0.926
[4,]   3 -0.414   0.979
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 6-4 Time-series stationarity test after the second order difference

6.3 White noise test and draw ACF and PACF plots

We used “Box-Ljung” method to perform white noise test. White noise test results shwed *P* values were 0.9986 for “lag=6” and 0.9999 for “lag=12” (Figure 6-5). We drew ACF and PACF plots for time-series (Figure 6-6 and Figure 6-7).

```
> Box.test(Values_diff,lag=6,type='Ljung-Box')

        Box-Ljung test

data:  Values_diff
X-squared = 0.43332, df = 6, p-value = 0.9986

> Box.test(Values_diff,lag=12,type='Ljung-Box')

        Box-Ljung test

data:  Values_diff
X-squared = 1.2702, df = 12, p-value = 0.9999
```

Figure 6-5 White noise test for time-series

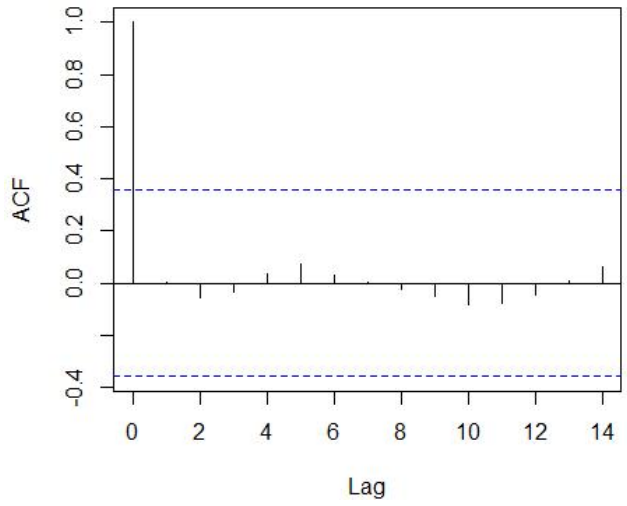

Figure 6-6 ACF plot for time-series

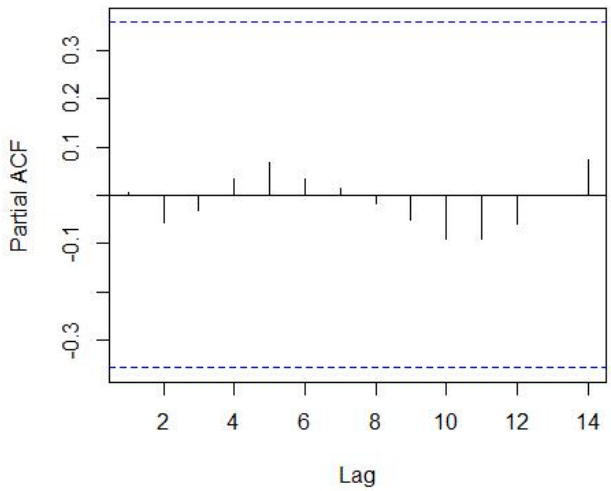

Figure 6-7 PACF plot for time-series

6.4 ARIMA model constructing

We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 6-1.

Table 6-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	268.6874	271.4898
ARIMA(1,2,1)	-	-
ARIMA(1,2,2)	-	-
ARIMA(2,2,0)	269.9579	274.1615
ARIMA(2,2,1)	-	-
ARIMA(2,2,2)	-	-

From table 6-1, we observed that there was lower AIC and BIC in ARIMA(1,2,0) model. Therefore, we chose ARIMA(1,2,0) model to fit the female ASPR data.

6.5 White noise test for residual

From figure 6-8, we found that residuals were white noise sequence (All $P>0.05$, Bottom Left). Therefore, the ARIMA(1,2,0) model was successful and reliable.

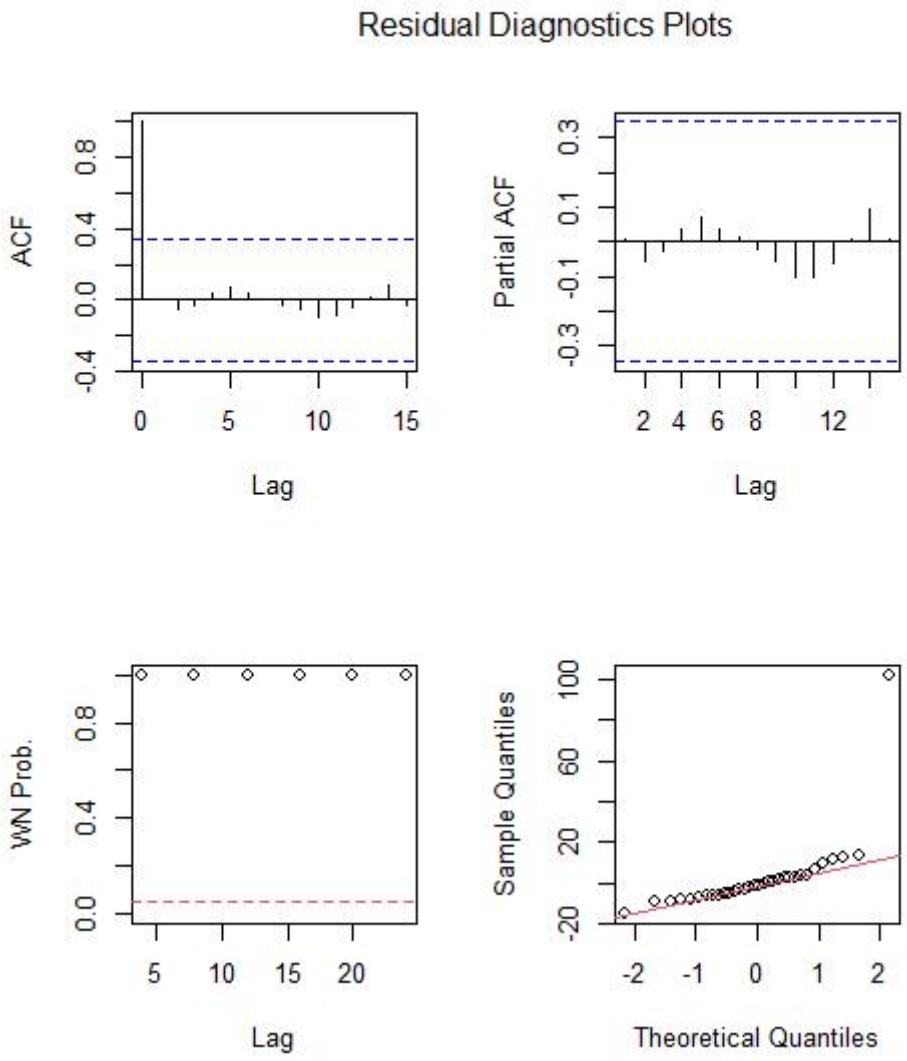

Figure 6-8 ARIMA(1,2,0) model test

7 Predict the total ASMR based on ARIMA model

7.1 Total ASMR time-series plot

The total ASMR trend from 1990 to 2021 was showed in figure 7-1.

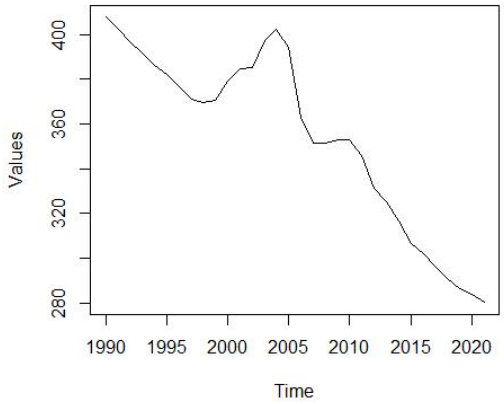

Figure 7-1 Total ASMR time-series trend plot

7.2 Difference of time-series

Figure 7-2 showed the first order difference of total ASMR time-series. Based on this, we further performed the second order difference (Figure 7-3). we found that the second order difference was more stationary than the first order difference.Time-series stationarity test after the second order difference was showed in figure 7-4 (*adf.test*).

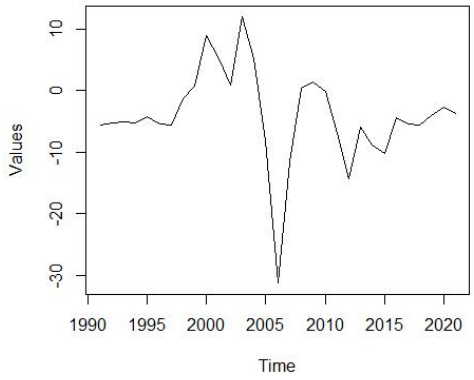

Figure 7-2 The first order difference of total ASMR time-serie

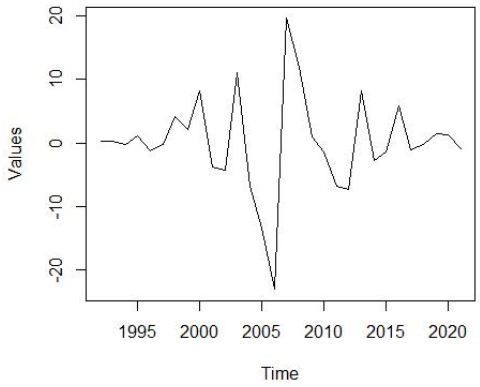

Figure 7-3 The second order difference of total ASMR time-serie

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag   ADF p.value
[1,]   0 -5.15    0.01
[2,]   1 -5.14    0.01
[3,]   2 -4.63    0.01
[4,]   3 -3.78    0.01
Type 2: with drift no trend
     lag   ADF p.value
[1,]   0 -5.06  0.0100
[2,]   1 -5.04  0.0100
[3,]   2 -4.53  0.0100
[4,]   3 -3.69  0.0112
Type 3: with drift and trend
     lag   ADF p.value
[1,]   0 -4.96  0.0100
[2,]   1 -4.94  0.0100
[3,]   2 -4.43  0.0100
[4,]   3 -3.60  0.0486
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 7-4 Time-series stationarity test after the second order difference

7.3 White noise test and draw ACF and PACF plots

We used “Box-Ljung” method to perform white noise test. White noise test results shwed *P* values were 0.3156 for “lag=6” and 0.7391 for “lag=12” (Figure 7-5). We drew ACF and PACF plots for time-series (Figure 7-6 and Figure 7-7).

```
> Box.test(Values_diff,lag=6,type='Ljung-Box')

        Box-Ljung test

data:  Values_diff
X-squared = 7.0567, df = 6, p-value = 0.3156

> Box.test(Values_diff,lag=12,type='Ljung-Box')

        Box-Ljung test

data:  Values_diff
X-squared = 8.5709, df = 12, p-value = 0.7391
```

Figure 7-5 White noise test for stationary time-series

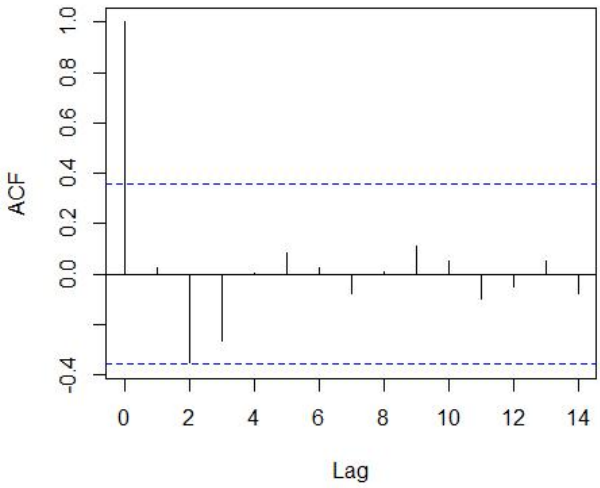

Figure 7-6 ACF plot for time-series

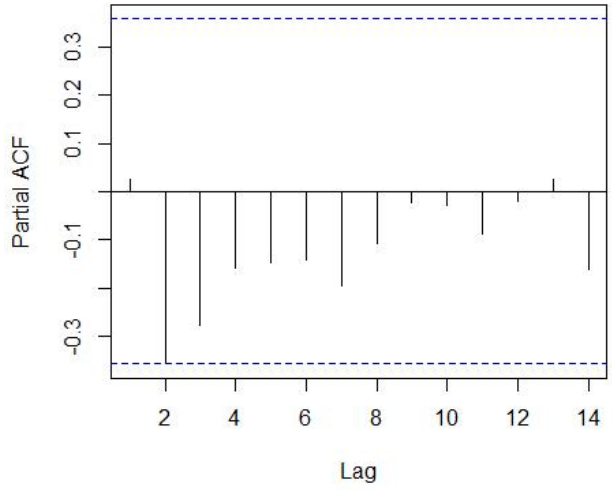

Figure 7-7 PACF plot for time-series

7.4 ARIMA model constructing

We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 7-1.

Table 7-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	211.1609	213.9633
ARIMA(1,2,1)	212.6816	216.8852
ARIMA(1,2,2)	205.9011	211.5059
ARIMA(2,2,0)	209.4173	213.6209
ARIMA(2,2,1)	205.0152	210.6200
ARIMA(2,2,2)	207.0056	214.0116

From table 7-1, we observed that there was lower AIC and BIC in ARIMA(2,2,1) model. Therefore, we chose ARIMA(2,2,1) model to fit the total ASMR data.

7.5 White noise test for residual

From figure 7-8, we found that residuals were white noise sequence (All P>0.05, Bottom Left). Therefore, the ARIMA(2,2,1) model was successful and reliable.

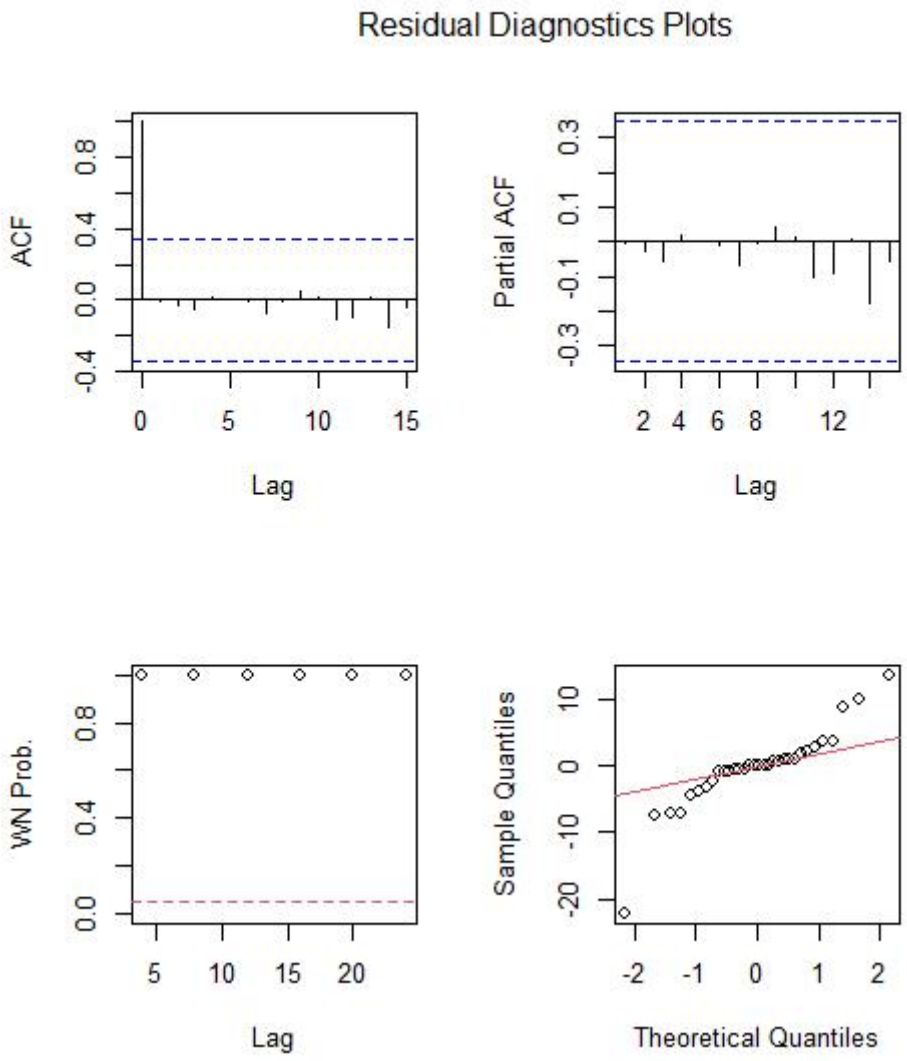

Figure 7-8 ARIMA(2,2,1) model test

8 Predict the male ASMR based on ARIMA model

8.1 Male ASMR time-series plot

The male ASMR trend from 1990 to 2021 was showed in figure 8-1.

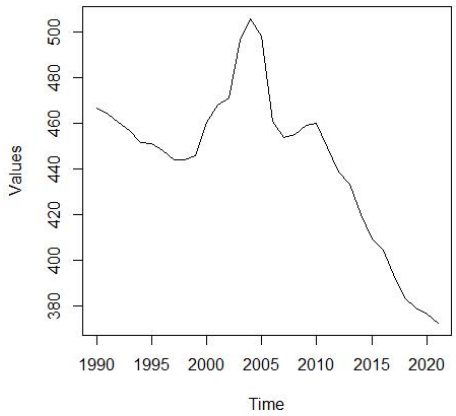

Figure 8-1 Male ASMR time-series trend plot

8.2 Difference of time-series

Figure 8-2 showed the first order difference of male ASMR time-series. Based on this, we further performed the second order difference (Figure 8-3). we found that the second order difference was more stationary than the first order difference.Time-series stationarity test after the second order difference was showed in figure 8-4 (*adf.test*).

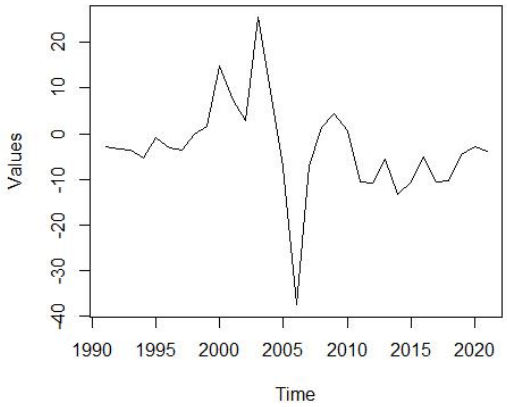

Figure 8-2 The first order difference of male ASMR time-serie

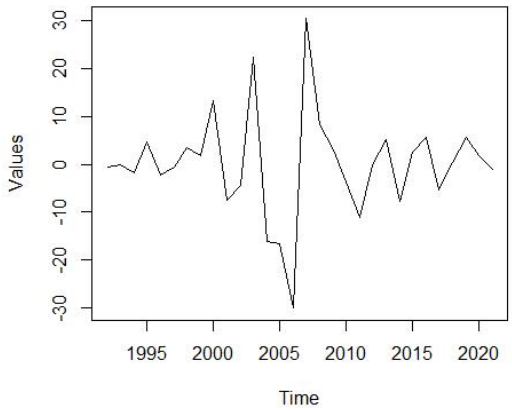

Figure 8-3 The second order difference of male ASMR time-serie

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag   ADF p.value
[1,]   0 -5.96    0.01
[2,]   1 -5.00    0.01
[3,]   2 -5.09    0.01
[4,]   3 -3.83    0.01
Type 2: with drift no trend
     lag   ADF p.value
[1,]   0 -5.85    0.01
[2,]   1 -4.90    0.01
[3,]   2 -4.98    0.01
[4,]   3 -3.75    0.01
Type 3: with drift and trend
     lag   ADF p.value
[1,]   0 -5.74  0.0100
[2,]   1 -4.80  0.0100
[3,]   2 -4.88  0.0100
[4,]   3 -3.65  0.0449
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 8-4 Time-series stationarity test after the second order difference

8.3 White noise test and draw ACF and PACF plots

We used “Box-Ljung” method to perform white noise test. White noise test results shwed *P* values were 0.3727 for “lag=6” and 0.7765 for “lag=12” (Figure 8-5). We drew ACF and PACF plots for time-series (Figure 8-6 and Figure 8-7).

```
> Box.test(values_diff,lag=6,type='Ljung-Box')

        Box-Ljung test

data:  values_diff
X-squared = 6.4691, df = 6, p-value = 0.3727

> Box.test(values_diff,lag=12,type='Ljung-Box')

        Box-Ljung test

data:  values_diff
X-squared = 8.1101, df = 12, p-value = 0.7765
```

Figure 8-5 White noise test for stationary time-series

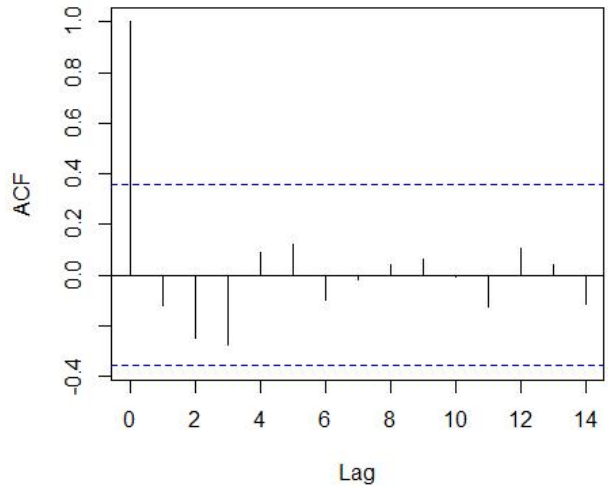

Figure 8-6 ACF plot for time-series

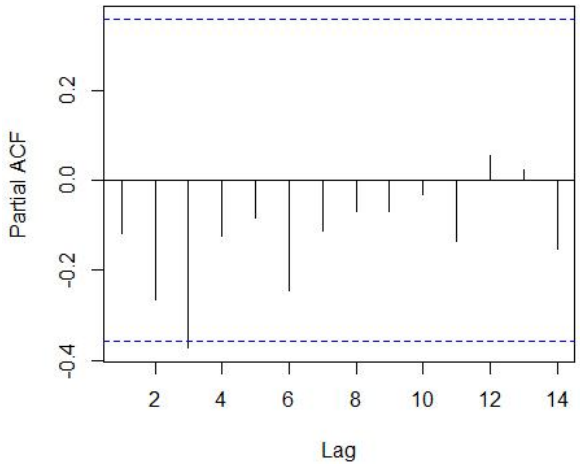

Figure 8-7 PACF plot for time-series

8.4 ARIMA model constructing

We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 8-1.

Table 8-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	232.2933	235.0957
ARIMA(1,2,1)	227.2654	231.4690
ARIMA(1,2,2)	228.4488	234.0535
ARIMA(2,2,0)	232.2557	236.4593
ARIMA(2,2,1)	228.0164	233.6212
ARIMA(2,2,2)	229.9487	236.9547

From table 8-1, we observed that there was lower AIC and BIC in ARIMA(1,2,1) model. Therefore, we chose ARIMA(1,2,1) model to fit the male ASMR data.

8.5 White noise test for residual

From figure 8-8, we found that residuals were white noise sequence (All $P>0.05$, Bottom Left). Therefore, the ARIMA(1,2,1) model was successful and reliable.

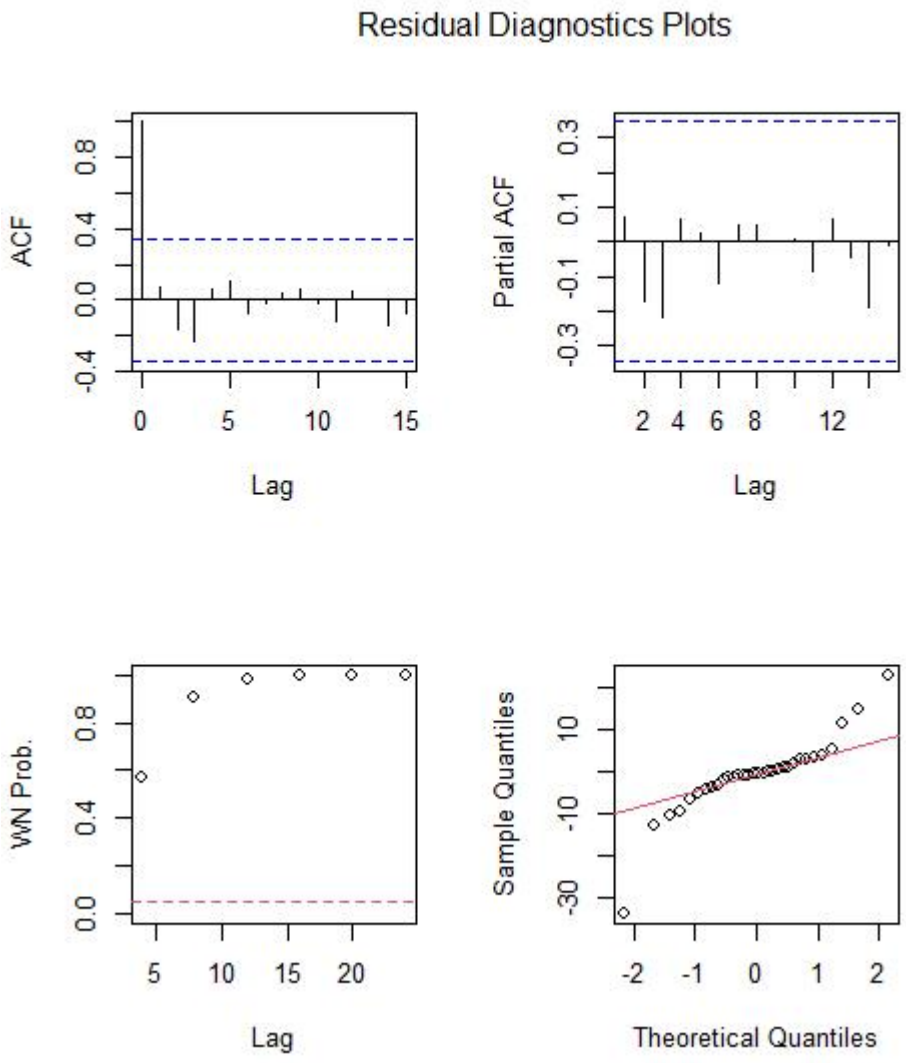

Figure 8-8 ARIMA(1,2,1) model test

9 Predict the female ASMR based on ARIMA model

9.1 Female ASMR time-series plot

The female ASMR trend from 1990 to 2021 was showed in figure 9-1.

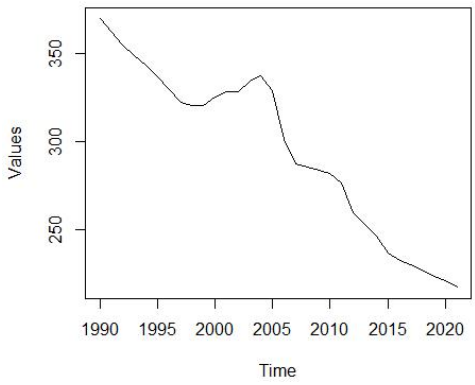

Figure 9-1 Female ASMR time-series trend plot

9.2 Difference of time-series

Figure 9-2 showed the first order difference of female ASMR time-series. Based on this, we further performed the second order difference (Figure 9-3). we found that the second order difference was more stationary than the first order difference.Time-series stationarity test after the second order difference was showed in figure 9-4 (*adf.test*).

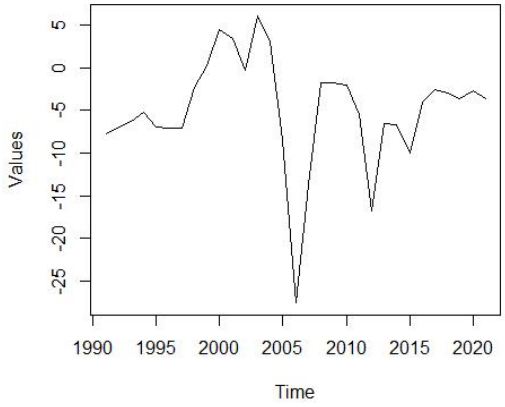

Figure 9-2 The first order difference of female ASMR time-serie

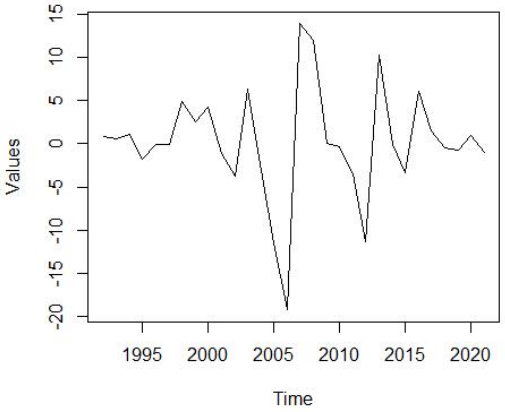

Figure 9-3 The second order difference of female ASMR time-serie

```
Augmented Dickey-Fuller Test
alternative: stationary

Type 1: no drift no trend
     lag   ADF p.value
[1,]   0 -5.11    0.01
[2,]   1 -5.30    0.01
[3,]   2 -4.13    0.01
[4,]   3 -3.92    0.01
Type 2: with drift no trend
     lag   ADF p.value
[1,]   0 -5.02    0.01
[2,]   1 -5.20    0.01
[3,]   2 -4.05    0.01
[4,]   3 -3.83    0.01
Type 3: with drift and trend
     lag   ADF p.value
[1,]   0 -4.93  0.0100
[2,]   1 -5.09  0.0100
[3,]   2 -3.96  0.0238
[4,]   3 -3.74  0.0385
----
Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Figure 9-4 Time-series stationarity test after the second order difference

9.3 White noise test and draw ACF and PACF plots

We used “Box-Ljung” method to perform white noise test. White noise test results shwed *P* values were 0.2865 for “lag=6” and 0.5048 for “lag=12” (Figure 9-5). We drew ACF and PACF plots for time-series (Figure 9-6 and Figure 9-7).

```
> Box.test(Values_diff,lag=6,type='Ljung-Box')

        Box-Ljung test

data:  Values_diff
X-squared = 7.3869, df = 6, p-value = 0.2865

> Box.test(Values_diff,lag=12,type='Ljung-Box')

        Box-Ljung test

data:  Values_diff
X-squared = 11.284, df = 12, p-value = 0.5048
```

Figure 9-5 White noise test for stationary time-series

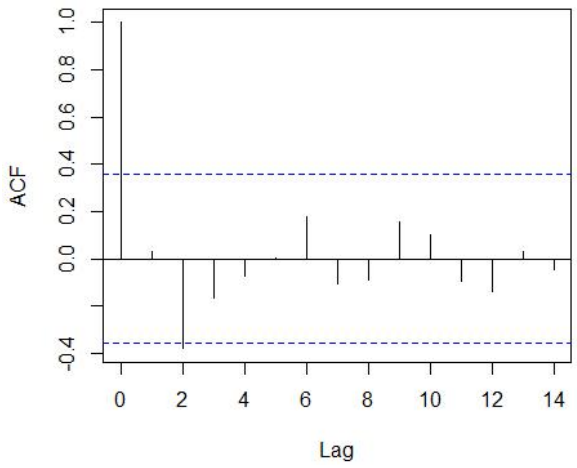

Figure 9-6 ACF plot for time-series

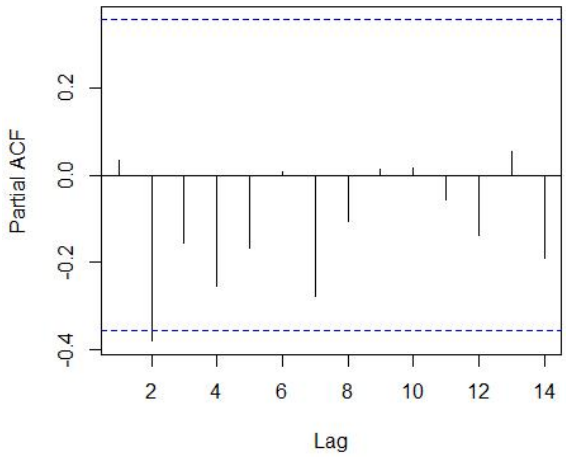

Figure 9-7 PACF plot for time-series

9.4 ARIMA model constructing

We selected optimal ARIMA parameters (p, d, q) based on Akaike information criterion (AIC) and Bayesian information criterion (BIC). The results of selecting ARIMA parameters were showed in table 9-1.

Table 9-1 The results of selecting ARIMA parameters

Models	AIC	BIC
ARIMA(1,2,0)	200.9881	203.7905
ARIMA(1,2,1)	201.9804	206.1840
ARIMA(1,2,2)	195.0999	200.7047
ARIMA(2,2,0)	198.5590	202.7626
ARIMA(2,2,1)	194.9204	200.5252
ARIMA(2,2,2)	196.6981	203.7041

From table 9-1, we observed that there was lower AIC and BIC in ARIMA(2,2,1) model. Therefore, we chose ARIMA(2,2,1) model to fit the female ASMR data.

9.5 White noise test for residual

From figure 9-8, we found that residuals were white noise sequence (All $P>0.05$, Bottom Left). Therefore, the ARIMA(2,2,1) model was successful and reliable.

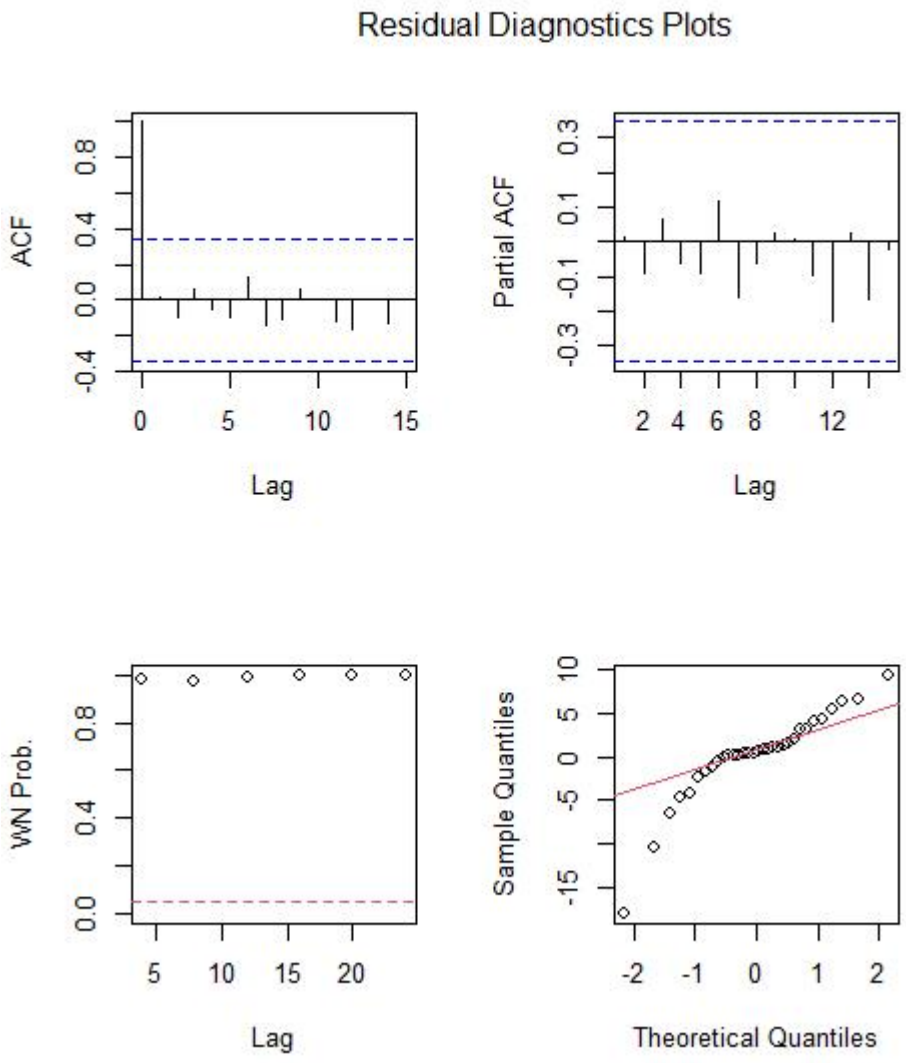

Figure 9-8 ARIMA(2,2,1) model test