Chapter 4

Time Series Analysis

In Chapter 3 we investigated the six components of the monthly series of petroleum demand (consumption) and supply (imports plus production) in Thailand over the period of 16 years from 1984 to 1999. We began by plotting the monthly changes against the levels, and found that it was necessary to take logarithms of these amounts to satisfy the statistical assumption of constant volatility. We then fitted two separate statistical models to the components as follows.

(a) A model containing a linear trend with a common slope for each component;

(b) Two-way analysis of variance, using component and quarter as the two factors.

These models respectively accounted for 93.4% and 95% of the r-squared goodness-of-fit for the consumption data, and 92.9% and 94.2% for the imports and production data.

Finally, we plotted the demand and supply data as time series, and fitted straight-line models to linear models to the relations between the supply and demand for each component. On the basis of this analysis, we found close relations between the monthly supply and demand for all of the components. We found that the supply of LPG, regular, and premium gasoline exceeded the consumption in the last four years (from 1996 to 1999).

The preliminary analysis described in Chapter 3 does not take into account the autocorrelations between values at successive periods occurring in time series data. In this chapter we fit time series models.

4.1 The Consumption Data

Figure 4.1 shows a time series analysis plot of the HSD monthly consumption amounts, expressed in base 10 logarithms. The fitted model consists simply of a linear

trend. The slope is 0.0031, which is close to the common slope estimate 0.0032 obtained in the preliminary analysis shown in Table 3.3.

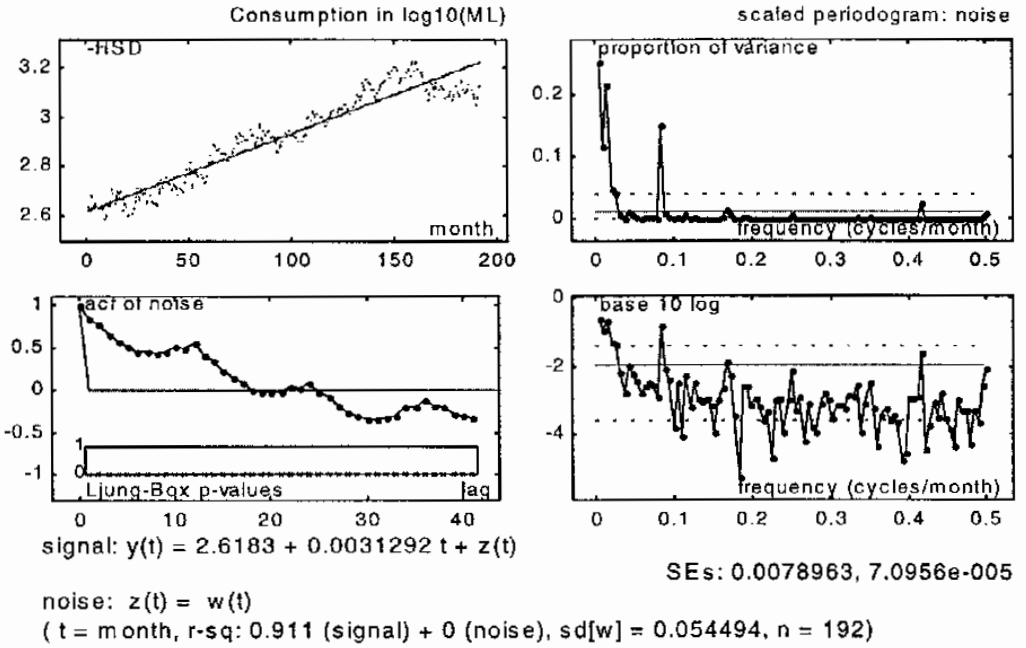


Figure 4.1: Time series, periodogram, and correlogram of HSD consumption

Figure 4.1 also includes plots of the periodogram and its logarithm (right-hand panels) and the autocorrelation function (correlogram) of the residuals (bottom left panel). The autocorrelation function is highly structured, showing that successive observations in the series are not independent. Our objective is to find a model that accounts for these correlations.

The periodogram has peaks at frequencies 1, 3 and 16 cycles. Since the length of the series is 192 months, these correspond to cycles at 16 years, 5.33 years, and 12 months. The 16-year cycle simply indicates the trend is not exactly linear, but is better fitted by a sine wave, which accommodates the downturn during the years 1997-1999. The annual cycle is simply a seasonal effect, indicating that HSD fuel consumption is highest around March and lowest around September. The cycle every 5.33 years is more difficult to explain, but might have something to do with economic cycles.

The graph of the logarithm of the periodogram also shows that the periodogram decreases with increasing frequency. This indicates that we should fit an

autoregressive model to account for the high correlations at short lags in the correlogram.

Figure 4.2 shows the time series analysis after fitting cyclic components at frequencies 1, 2, 3 and 16 cycles, and autoregressive terms at lags 1 and 2. The residuals pass the Ljung-Box test of independence, as you can see from the absence of any correlation in these residuals shown in the lower left panel, so the model gives a satisfactory fit. The r-squared goodness-of-fit is 98.3%.

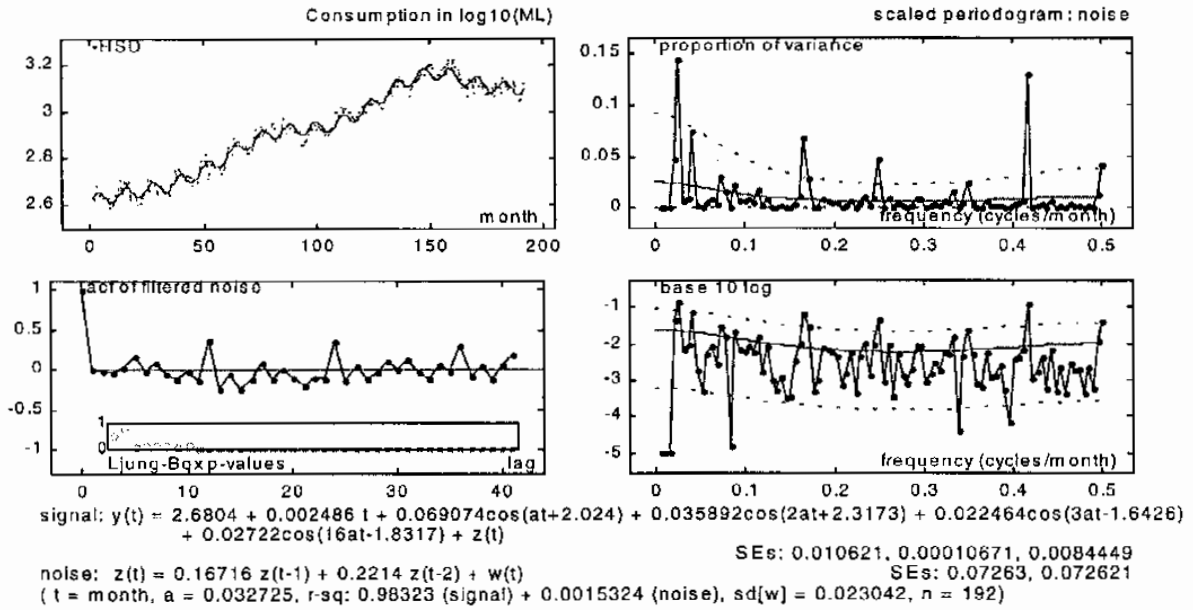


Figure 4.2: Time series analysis of HSD consumption, after fitting harmonic and autoregressive components

Figures 4.3 and 4.4 show the results after fitting the model to the fuel oil and JP consumption amounts. Each time series model has (a) a linear trend, (b) cyclic components at frequencies 1, 2, 3 and 16, and (c) two autoregressive parameters at lags 1 and 2. However, it was necessary to fit another cyclic component at frequency 48 cycles, in order to obtain a satisfactory fit of the model to the JP series. This component corresponds to a quarterly seasonal effect. The r-squared goodness-of-fit values are 97.0% and 99.0%, respectively.

All three series also have a statistically significant spike in the periodogram at 80 cycles. However, there does not seem to be any explanation for a cycle at this period, which corresponds to 192/80 = 2.4 months.

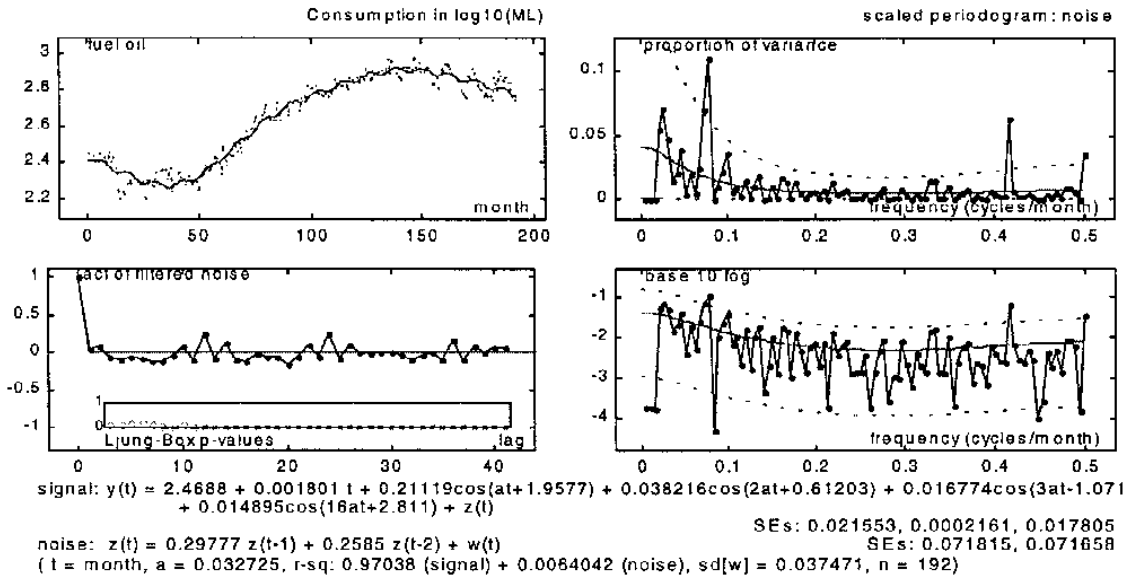


Figure 4.3: Time series analysis of fuel oil consumption, after fitting harmonic and autoregressive components

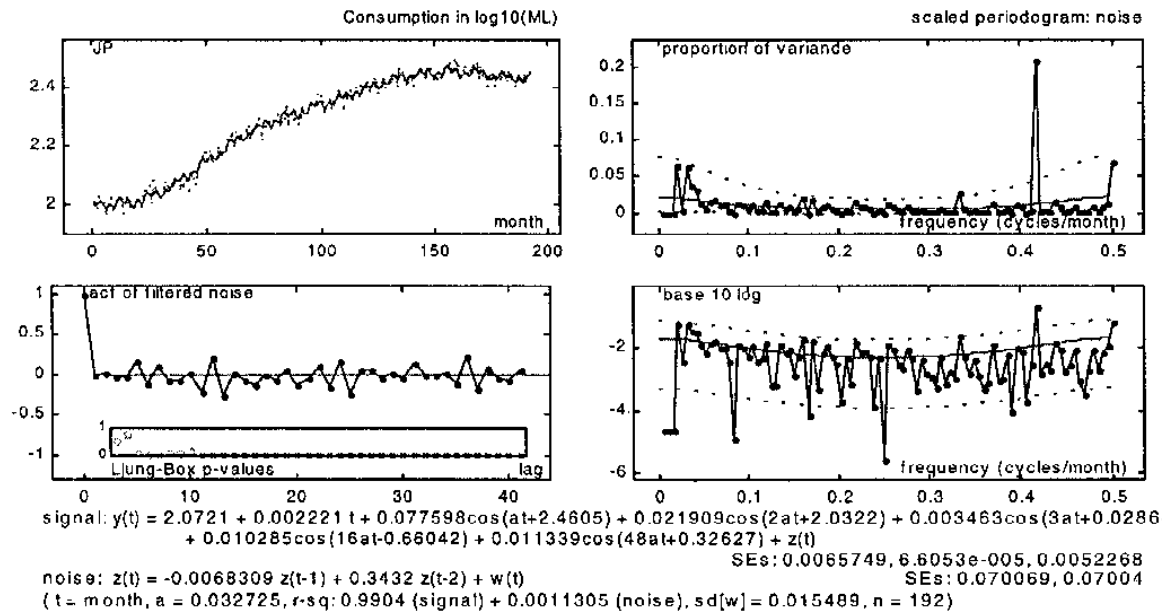


Figure 4.4: Time series analysis of JP consumption, after fitting harmonic and autoregressive components

Figures 4.5 – 4.7 show the results after fitting the same model to the other three components of consumption. It was necessary to fit two furture seasonal components with frequencies 48 and 64 cycles to get a satisfactory fit to the premium and regular gasoline consumption series.

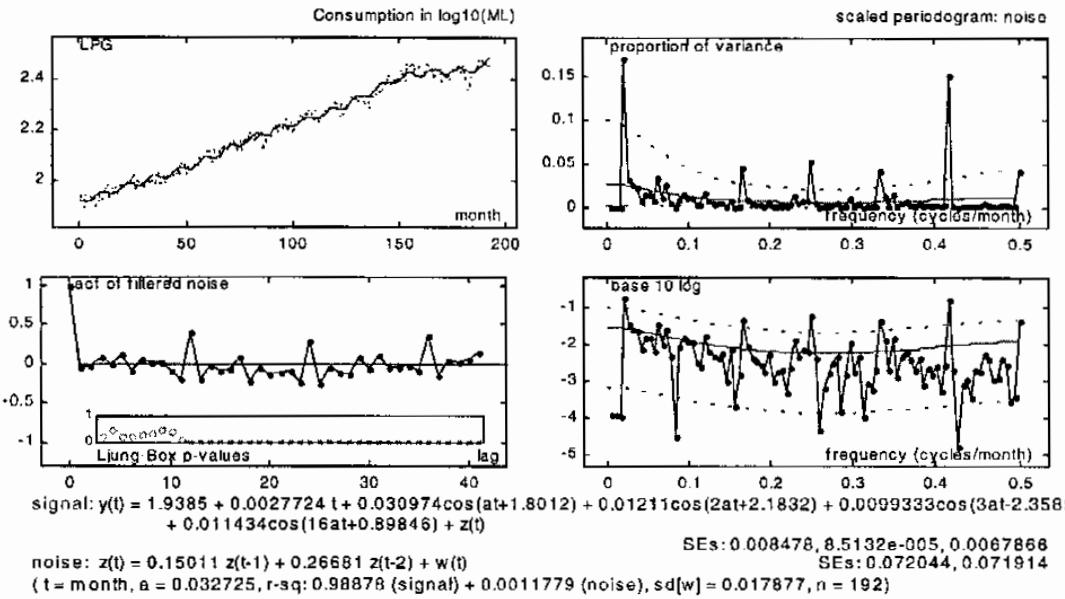


Figure 4.5: Time series analysis of LPG consumption, after fitting harmonic and autoregressive components

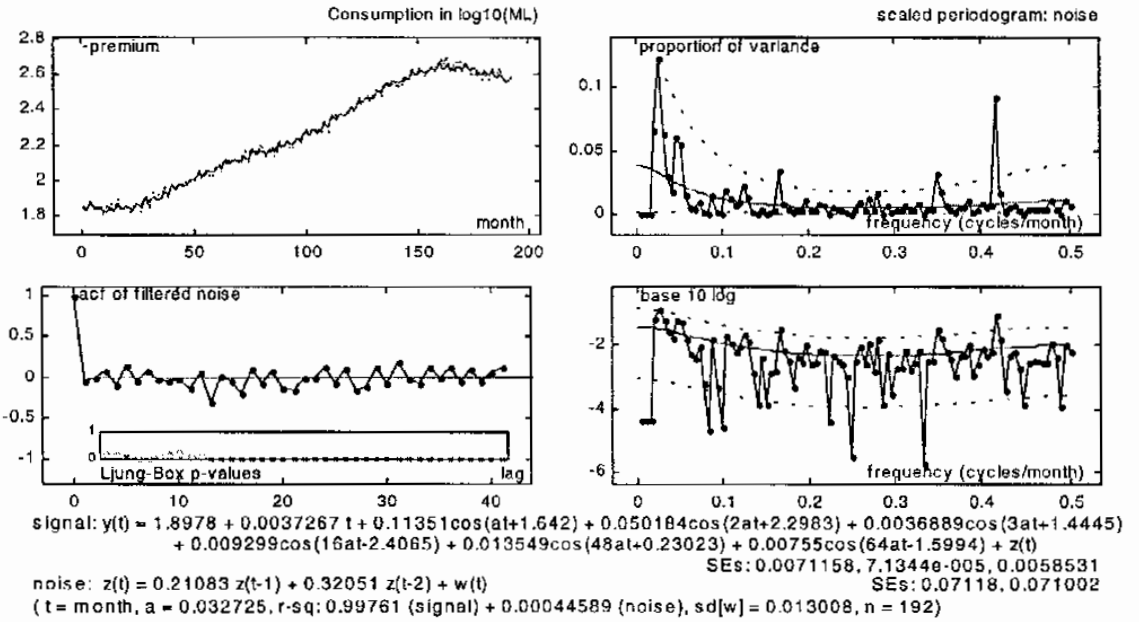


Figure 4.6: Time series analysis of premium gasoline consumption, after fitting harmonic and autoregressive components

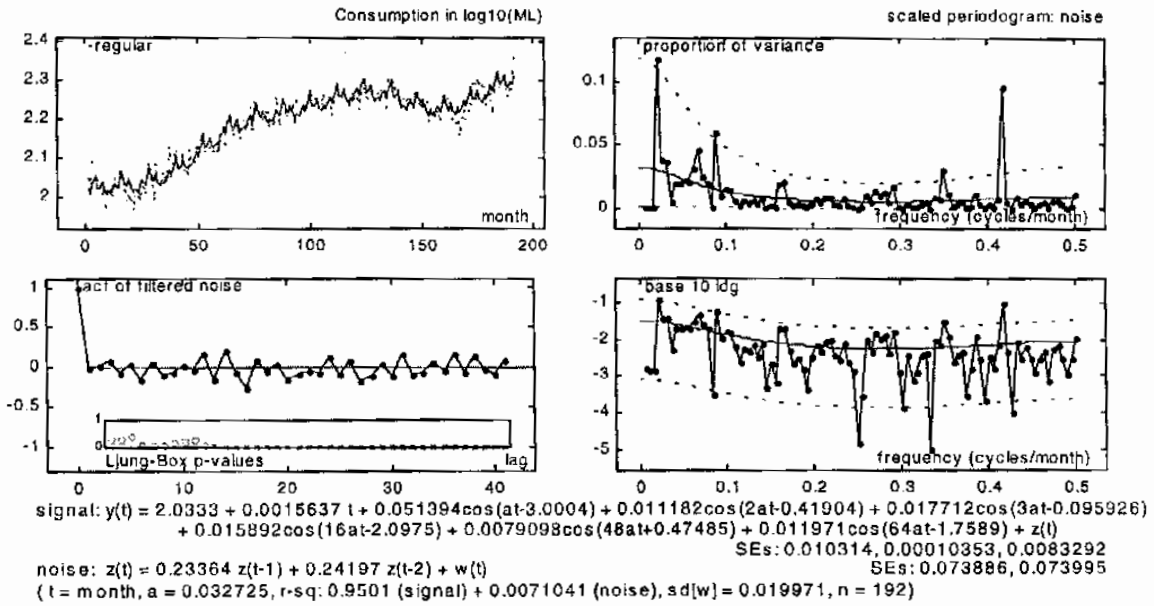


Figure 4.7: Time series analysis of regular gasoline consumption, after fitting harmonic and autoregressive components

The r-square goodness-of-fit statistics remain high for the other three components. The value for LPG is 98.9%, the value for premium gasoline 99.7%. However, the r-squared value for regular gasoline is relatively low, only 95.0%.

In the next section we look at the time series for the supply data.

4.2 The Imports and Production Data

Figures 4.8 to 4.13 show the results after fitting the model to the HSD, fuel oil, JP, LPG, premium gasoline and regular gasoline imports and production totals. Each time series model has (a) a linear trend, (b) cyclic components at frequencies 1, 2 and 16, and (c) two autoregressive parameters at lags 1 and 2. The model in each case has an approximately linear trend and a quarterly seasonal effect. The r-squared goodness-of-fit statistics are shown in table 4.1.

The r-square goodness-of-fit statistics are high for most components. The highest value is for premium (97.1%). However, the r-squared values for regular gasoline are relatively low, only 84.3%.

Figures 4.11 show the results after fitting the model to the LPG imports and production totals. Time series model has (a) a linear trend, (b) cyclic components at frequencies 1, 2 and 16, and (c) two autoregressive parameters at lags 1 and 2. These components correspond to a quarterly seasonal effect.

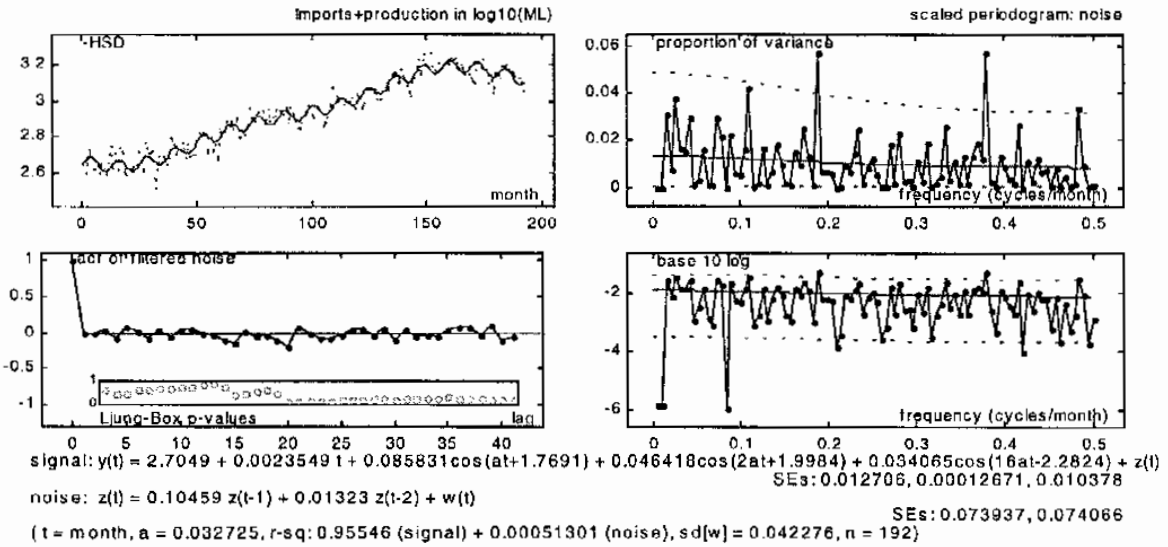
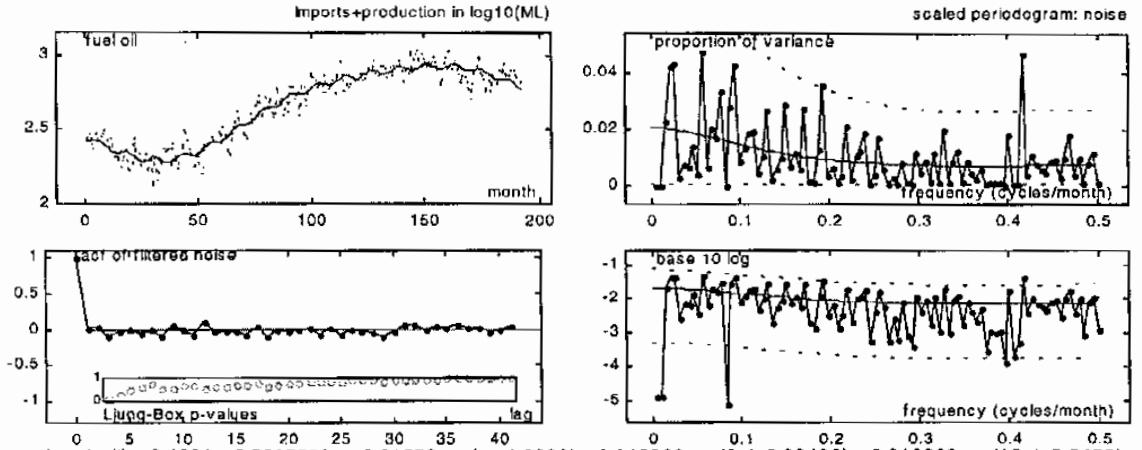


Figure 4.8: Time series analysis of HSD imports and production, after fitting harmonic and autoregressive components

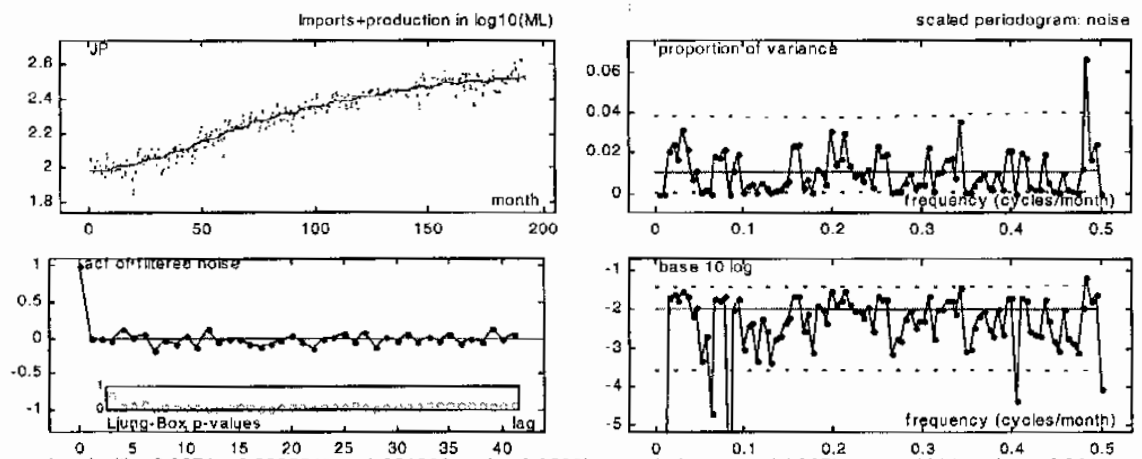


signal: y(t) = 2.4891 + 0.0017586 t + 0.21573cos(at+1.8903) + 0.043869cos(2at+0.83423) + 0.018269cos(16at+2.6499) + z(t)
SEs: 0.023998, 0.00023898, 0.019834

noise: z(t) = 0.22948 z(t-1) + 0.082172 z(t-2) + w(t)
SEs: 0.073602, 0.073602

(t = month, a = 0.032725, r-sq: 0.9312 (signal) + 0.0047311 (noise), sd[w] = 0.064316, n = 192)

Figure 4.9: Time series analysis of fuel oil imports and production, after fitting harmonic and autoregressive components



signal: y(t) = 2.0271 + 0.0028249 t + 0.051969cos(at+2.6535) + 0.01079cos(2at+1.7367) + 0.0072051cos(16at-0.72365) + z(t)
SEs: 0.012619, 0.00012593, 0.010273

noise: z(t) = -0.012273 z(t-1) + 0.0084977 z(t-2) + w(t)
SEs: 0.074116, 0.074642

(t = month, a = 0.032725, r-sq: 0.93503 (signal) + 1.7773e-005 (noise), sd[w] = 0.047326, n = 192)

Figure 4.10: Time series analysis of JP imports and production, after fitting harmonic and autoregressive components

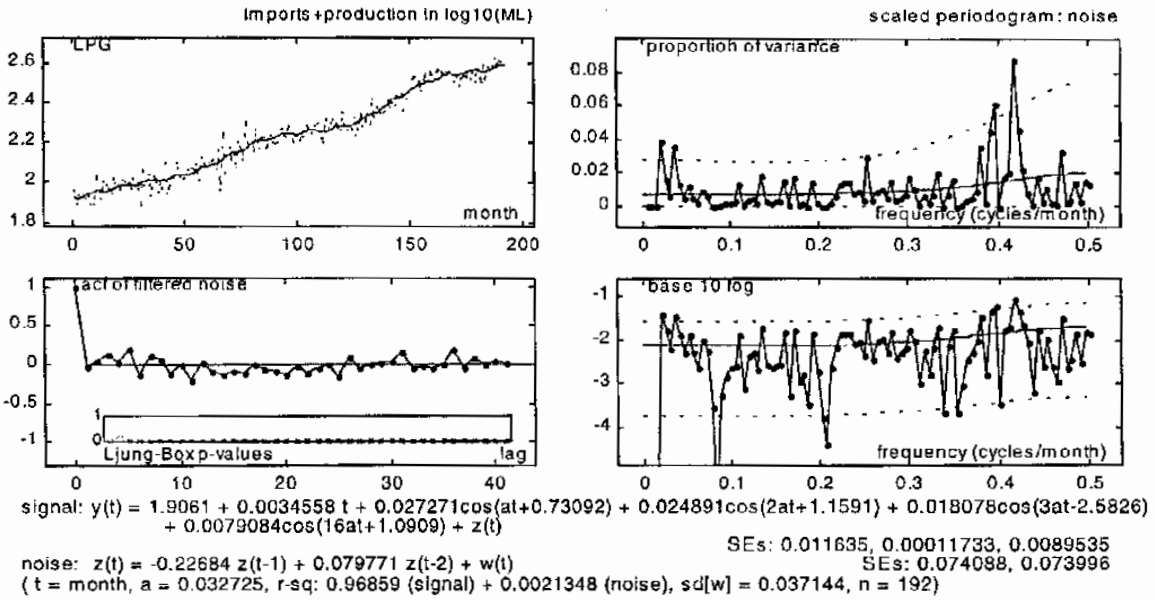


Figure 4.11: Time series analysis of LPG imports and production, after fitting harmonic and autoregressive components

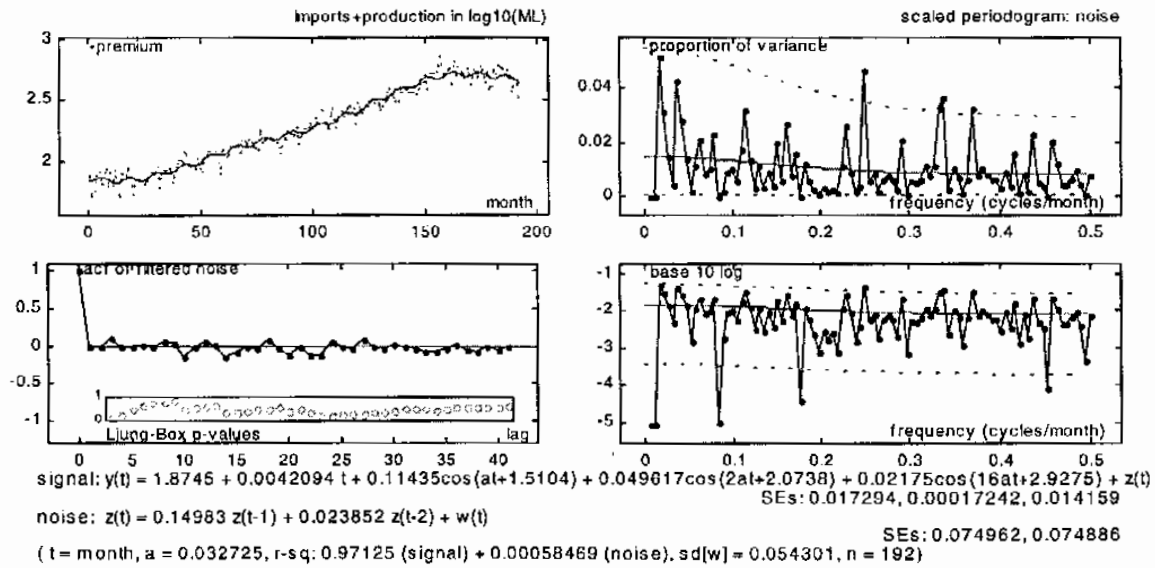


Figure 4.12: Time series analysis of premium imports and production, after fitting harmonic and autoregressive components

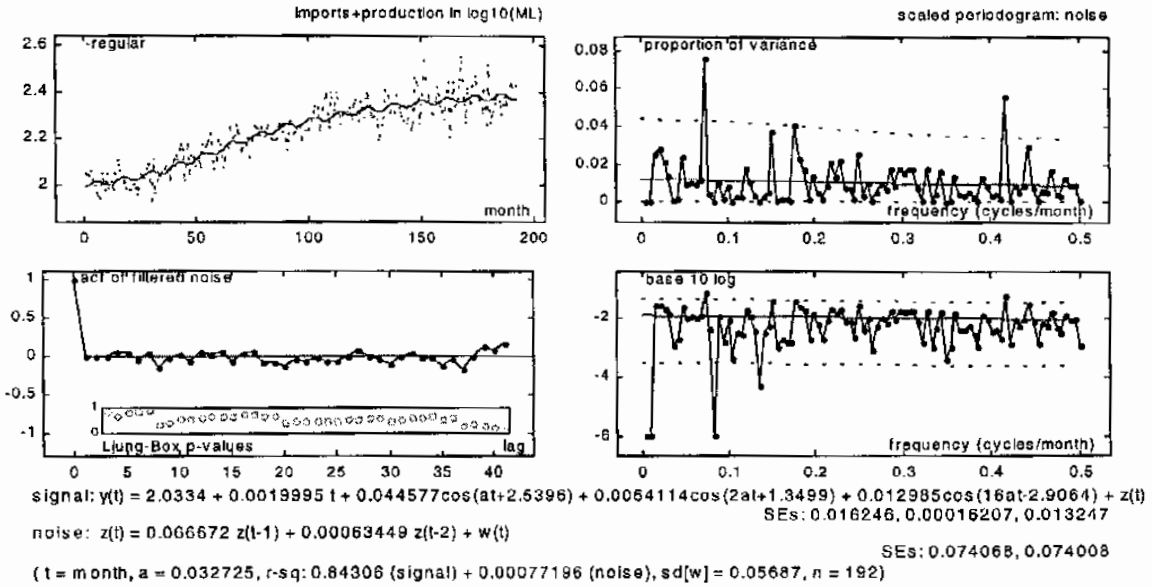


Figure 4.13: Time series analysis of regular imports and production, after fitting harmonic and autoregressive components

4.3 Summaries of Consumption and Imports and Production Data

Tables 4.1 and 4.2 show the estimated parameters in the models for consumption and imports and production for each component. The premium gasoline has the highest r-squares in both consumption (99.8%) and imports and production (97.3%), but the lowest are regular in consumption (95.0%) and in imports and production (84.3%).

Consumption

component	HSD	Fuel oil	JP	LPG	premium	regular
r^2 (%)	98.3	97.0	99.0	98.9	99.8	95.0
trend slope	0.003	0.002	0.002	0.003	0.004	0.002
Amplitude A_1	0.069	0.211	0.078	0.031	0.114	0.051
Amplitude A_2	0.036	0.038	0.022	0.012	0.050	0.011
Amplitude A_3	0.023	0.017	0.004	0.010	0.004	0.018
Amplitude A_{16}	0.027	0.015	0.010	0.011	0.010	0.159
Autoreg: a_1	0.167	0.298	–0.007	0.150	0.211	0.234
Autoreg: a_2	0.221	0.259	0.034	0.267	0.321	0.242

Table 4.1: Summaries of consumption of components

Imports and production

component	HSD	Fuel oil	JP	LPG	premium	regular
r^2 (%)	95.5	93.1	93.5	96.9	97.1	84.3
Trend slope	0.002	0.002	0.003	0.003	0.004	0.002
Amplitude A_1	0.086	0.216	0.052	0.027	0.114	0.045
Amplitude A_2	0.046	0.044	0.011	0.025	0.050	0.006
Amplitude A_{16}	0.034	0.018	0.007	0.008	0.022	0.013
Autoreg: a_1	0.105	0.230	-0.012	0.227	0.150	0.067
Autoreg: a_2	0.013	0.082	0.008	0.080	0.024	0.001

Table 4.2: Summaries of imports and production of components