

Chapter 5

Conclusion and Discussion

5.1 Conclusion

As stated in Chapter 1, this study had the following objectives.

1. To investigate the patterns of supply and demand of petroleum products in Thailand.
2. To study the trends of supply and demand of petroleum products in Thailand.

We divided the petroleum into six main components, high speed diesel, fuel oil, jet petrol, LPG, premium gasoline and regular gasoline. The data for our study cover the period of 192 months from January 1984 to December 1999. To satisfy the statistical assumption of constant variance, we found that both the consumption and imports and production total amounts needed to be log-transformed.

To investigate the consumption patterns, we first used linear regression analysis to fit a model of the form $y_j = a_j + b x$, where y_j is the consumption of component j for month x . After fitting this model, we found that the component with the highest consumption over the period was HSD fuel. The component with the next highest consumption was fuel oil, and the other four components were lower, with no statistically significant differences between their consumption amounts.

While the linear regression model for modelling consumption gave an r-squared goodness-of-fit of 93.4%, a model based on two-way analysis of variance with quarterly effects provided a better fit (r-squared 95.0%). This model confirmed the results from the regression analysis, showing that HSD had the highest average consumption, corresponding to $10^{2.92} = 832$ ML/month, and that the average for fuel oil was $10^{2.64} = 437$ ML/month. Similarly, this model gave average consumption of $10^{2.29} = 195$ ML/month for JP fuel, $10^{2.26} = 182$ ML/month for premium gasoline, and $10^{2.2} = 158$ and $10^{2.18} = 151$ ML/month for LPG and regular gasoline.

We also examined the correlation between petroleum consumption components, finding them to be generally high. The highest correlation coefficient (0.988) was observed between premium gasoline and LPG, while the lowest (0.859) was seen between premium and regular gasoline.

To investigate the patterns in the imports and production amounts, we again used linear regression analysis to fit the model of the form $y_j = a_j + b x$. After fitting this model, we found that the component with the highest imports and production amounts over the period was HSD fuel. The component with the next highest imports and production amounts was fuel oil, and the JP and premium gasoline and LPG and regular gasoline components were lower, with no statistically significant differences between their amounts.

While the linear regression model for modeling the petroleum supply gave an r-squared goodness-of-fit of 92.9%, the model based on two-way analysis of variance with quarterly effects provided a better fit (r-squared 94.2%). This model confirmed the results from the regression analysis, showing that HSD had the highest average imports and production amount, corresponding to $10^{2.93} = 851$ ML/month, and that the average for fuel oil was $10^{2.66} = 457$ ML/month. Similarly, this model gave average amounts of $10^{2.30} = 200$ and $10^{2.28} = 191$ ML/month for JP and premium gasoline, $10^{2.24} = 174$ ML/month for LPG, and $10^{2.23} = 170$ ML/month for regular gasoline.

Among the imports and production totals, the correlation coefficients were lower than those relating the imports and production amounts. The highest correlation coefficient (0.964) was observed between premium gasoline and HSD, while the lowest (0.862) was seen between LPG and fuel oil.

We also studied the relationships between the supply and demand amounts. On the whole, these amounts were very similar for each month for most components, except that the imports and production totals exceeded jet petrol, LPG and both regular and premium gasoline in 1999. Especially the LPG imports and production total exceeded consumption since 1996 to 1999. We also used simple linear regression analysis to study the relation between the supply and demand, finding the r-squared goodness-of-fit to range from 74.6% for regular gasoline to 96.2% for premium gasoline.

To answer the second objective, we examined the trends of petroleum demand and supply. In the preliminary analysis we first fitted a linear trend with the same slope for each component, but found that this model did not provide a satisfactory fit for either the consumption amounts or for the imports and production totals.

We then used time series analysis to provide a more acceptable model for the trends in petroleum supply and demand.

The patterns of the **demand model** comprise the following terms:

- (a) a trend involving a linear increase and three sinusoidal (harmonic) terms with periods 16, 8 and 5.33 years, respectively;
- (b) an annual seasonal component consisting of a sinusoidal term;
- (c) a residual series with two auto-regressive parameters at lags 1 and 2

The time series model for each petroleum product in month t is as follows:

(a) High speed diesel (HSD):

The model is $y(t) = 2.680 + 0.0025 t + 0.069\cos(at+2.024) + 0.036\cos(2at+2.317)$
 $+ 0.022\cos(3at-1.643) + 0.027\cos(16at-1.832) + z(t)$,

where $z(t) = 0.17 z(t-1) + 0.22 z(t-2) + 0.023 w(t)$, $a = 2\pi/192 = 0.032725$, and $w(t)$ is white noise. The r-squared for this model is 98.3%.

(b) fuel oil

The model is $y(t) = 2.489 + 0.0018 t + 0.211\cos(at+1.958) + 0.038\cos(2at+0.612)$
 $+ 0.015\cos(16at-2.811) + z(t)$,

where $z(t) = 0.298 z(t-1) + 0.259 z(t-2) + 0.037 w(t)$, and $w(t)$ is white noise. The r-squared is 97.0%.

(c) Jet petrol

The model is $y(t) = 2.072 + 0.0022 t + 0.078\cos(at+2.461) + 0.022\cos(2at+2.032)$
 $+ 0.003\cos(3at+0.029) + 0.010\cos(16at-0.660)$
 $+ 0.011\cos(48at+0.326) + z(t)$,

where $z(t) = 0.007 z(t-1) + 0.343 z(t-2) + 0.0155 w(t)$, and $w(t)$ is white noise. The r-squared is 99.04%.

(d) LPG

The model is $y(t) = 1.939 + 0.0028 t + 0.031 \cos(at+1.801) + 0.012 \cos(2at+2.183)$
 $+ 0.010 \cos(3at-2.359) + 0.010 \cos(16at+0.898) + z(t)$.

where $z(t) = 0.15 z(t-1) + 0.267 z(t-2) + 0.018 w(t)$, and $w(t)$ is white noise. The r-squared is 98.88%.

(e) Premium gasoline

The model is $y(t) = 1.878 + 0.0037 t + 0.114 \cos(at+1.642) + 0.050 \cos(2at+2.298)$
 $+ 0.004 \cos(3at+1.445) + 0.009 \cos(16at-2.407) + 0.014 \cos$
 $+ (48at+0.230) + 0.008 \cos(64at-1.599) + z(t)$.

where $z(t) = 0.211 z(t-1) + 0.321 z(t-2) + 0.013 w(t)$, and $w(t)$ is white noise. The r-squared is 99.76%.

(f) Regular gasoline

The model is $y(t) = 2.033 + 0.0016 t + 0.051 \cos(at+3.000) + 0.010 \cos(2at+0.419)$
 $+ 0.017 \cos(3at-0.096) + 0.016 \cos(16at-2.098) + 0.008 \cos$
 $+ (48at+0.475) + 0.012 \cos(64at-1.759) + z(t)$.

where $z(t) = 0.234 z(t-1) + 0.242 z(t-2) + 0.020 w(t)$, and $w(t)$ is white noise. The r-squared is 95.01%.

The patterns of the supply model comprise

- (a) a trend involving a linear increase and three sinusoidal (harmonic) terms with periods 16, 8 and 1 year, respectively;
- (b) an annual seasonal component consisting of a sinusoidal term;
- (c) a residual series with two auto-regressive parameters at lags 1 and 2

The time series model for each petroleum product in month t is as follows:

The patterns of **supply model** has

(a) High speed diesel(HSD)

The model is $y(t) = 2.705 + 0.0024 t + 0.086 \cos(at+1.769) + 0.046 \cos(2at+1.998)$
 $+ 0.034 \cos(16at-2.282) + z(t)$.

where $z(t) = 0.105 z(t-1) + 0.013 z(t-2) + 0.042 w(t)$, and $w(t)$ is white noise. The r-squared is 95.55%.

(b) fuel oil

The model is $y(t) = 2.489 + 0.0022t + 0.216\cos(at+1.89) + 0.044\cos(2at+0.834)$
 $+ 0.018\cos(16at-2.650) + z(t)$.

where $z(t) = 0.229 z(t-1) + 0.082 z(t-2) + 0.064 w(t)$, and $w(t)$ is white noise. The r-squared is 93.12%.

(c) Jet petrol

The model is $y(t) = 2.027 + 0.0028t + 0.052\cos(at+2.654) + 0.011\cos(2at+1.737)$
 $+ 0.007\cos(16at-0.724) + z(t)$.

where $z(t) = -0.012 z(t-1) + 0.008 z(t-2) + 0.047 w(t)$, and $w(t)$ is white noise. The r-squared is 93.50%.

(d) LPG

The model is $y(t) = 1.9061 + 0.0035t + 0.027\cos(at+0.731) + 0.025\cos(2at+1.159)$
 $+ 0.018\cos(3at-2.583) + 0.008\cos(16at+1.091) + z(t)$.

where $z(t) = -0.227 z(t-1) + 0.080 z(t-2) + 0.037 w(t)$, and $w(t)$ is white noise. The r-squared is 96.86%.

(e) Premium gasoline

The model is $y(t) = 1.875 + 0.0042t + 0.114\cos(at+1.510) + 0.050\cos(2at+2.074)$
 $+ 0.0218\cos(16at-2.928) + z(t)$.

where $z(t) = 0.150 z(t-1) + 0.024 z(t-2) + 0.054 w(t)$, and $w(t)$ is white noise. The r-squared is 97.13%.

(f) Regular gasoline

The model is $y(t) = 2.033 + 0.0020t + 0.045\cos(at+2.540) + 0.006\cos(2at+1.350)$
 $+ 0.013\cos(16at-2.901) + z(t)$.

where $z(t) = 0.067 z(t-1) - 0.0006 z(t-2) + 0.0569 w(t)$, and $w(t)$ is white noise. The r-squared is 84.31%.

Forecasting the next two-year (2000 to 2001), The trend of both LPG and regular gasoline 's demand will be increased, but fuel oil 's consumption will be decreased, while the others will be slightly increased. The trend of supply will be increased in JP and LPG, in the contrast fuel oil will be decreased, and the others will be slightly increased.

5.2 Discussion Limitations and Future Research

Although in 1999 The Thai Oil Company refinery was burned down, and this affected its production. But HSD, fuel oil, JP, LPG, premium and regular gasoline were still oversupplied, and exported 1,976, 330.8, 820.3, 1346.1, 1222.3 and 486.3 ML, respectively.

Because of The Demand Side Management (DSM) Programs such as energy-efficient appliances, the Car Pool campaign and the Octane campaign (National Energy Policy Office, 1997) have effected to the trend of consumption will be slightly increased within two year after this year. Exception was fuel oil, it was decreased because of the government policies promote alternative energy substitution of fuel oil by natural gas in power plants.

Although the government promotes and encourages the exploration and development of domestic petroleum resources by modern technology, but the petroleum should be used more efficiently and economical. Besides we should find alternative energy to compensate petroleum imports from other countries.

Limitations

In this study, using monthly data from the National Energy Policy Office of Thailand published for the 16-year period from 1984 to 1999, we investigated the patterns and trends of petroleum consumption and supply, classified into the six major types of petroleum. We used statistical methods to compare and relate these components over the time period. And we used statistical time series analysis methods to fit models that could be used for short-term forecasting.

There are many problems and limitations in our study.

First, we did not investigate the determinants of petroleum supply and demand. These might include demographic, socio-economic and political (i.e., public policy) factors. These factors would be expected to have major effects on petroleum consumption and production.

Second, we did not investigate the regional variation in petroleum consumption. It is likely that the consumption as well as the production of petroleum components will

vary substantially from region to region in Thailand, and that there will be major differences between urban and rural area.

Future research

We should get the exports data, the stock data and the petroleum prices for analysis. However, important as these issues are, addressing them was beyond the scope of this thesis. Hopefully they will be investigated in further studies.