Chapter 4

Estimation of Energy Demand Formulas

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Chapter 4

Estimation of Energy Demand Formulas

Energy is an important commodity for developing the economy. As economic activities increase, demand for energy increases. Changes in energy prices directly influence energy consumption and economic growth. Rising energy prices bring an incentive to use energy sources more efficiently and conservatively, resulting in lower energy consumption. The increase in energy prices, however, leads to inflation because the cost of other goods increases and gross domestic product (GDP) decreases. Therefore, there is a direct link between energy consumption and socio-economic variables such as energy price and economic output (or GDP). Logically, an increase in GDP leads to an increase in energy consumption but, on the contrary, an increase in energy prices results in lower energy consumption.

This chapter focuses on the estimation of energy demand formulas based on historical data on energy consumption, socio-economic data, and activity indicators used to forecast energy demand until 2040.

1. Methodology

The demand function was estimated using the econometrics approach, which is a top-down approach linking the macroeconomic model and energy model.

In the econometrics approach, energy demand is modelled as a function of macroeconomic activities such as income (or GDP), relative prices amongst sources of energy, and energy consumption at previous period.

$$E = f(Y, Pe/CPI) \quad or \quad E = f(Y, Pe/CPI, E\text{-}1)$$

Where:

E : *Energy demand*
Y : *Income (or GDP)*
Pe : *Energy price*
CPI : *Consumer price index*
Pe/CPI : *Relative energy price over CPI*
$E\text{-}1$: *Energy consumption at previous period*

The relationships amongst the above variables are derived using regression analysis software Microfit, which carries out econometrics analysis, estimating ordinary least squares (OLS) and testing equations, data processing, file management, graphic display, estimation, hypothesis testing, and forecasting using univariate and

multivariate model specifications.

Future energy demand for various energy sources will be forecasted using the estimated formulas mentioned above with the assumed future values of the macroeconomic, energy price, and other activity indicators. However, not all energy consumption of the sectors could be estimated as a demand formula because of data limitations.

To estimate the energy demand formulas for economic activities in the industry, transport, commercial, and residential sectors, we disaggregate energy consumption by sector into type of energy, such as gas, petroleum products, electricity, and coal consumption, and then test the regression results for their relationship with GDP, energy prices, and other related indicators.

In cases where regression analysis is not applicable because of insufficient data or failure to derive a statistically effective equation, other exogenous approaches such as growth of GDP or share of percentage were applied.

2. Estimation of Energy Demand Formulas

2.1. Industry

Total energy consumption in industry is not broken down into subsectors. On the basis of fuel type, the total energy consumption each year from 2000 to 2016 is the sum of the different types of fuel: coal; electricity; natural gas; petroleum products (diesel and fuel oil); and others (fuelwood and charcoal, amongst others).

Based on available data, demand formulas have been estimated for the type of fuel, if applicable.

a) Sub-bituminous Coal Demand in Industry

Because of the limitation of national energy data, the domestic coal price for industry (wholesale price) was not available to use as an explanatory variable in the energy demand formula, so that the relative price of crude oil (RPOIL), defined as the price of crude oil (POILJ)/exchange rate (EXR)/GDP deflator (PGDP), instead of the domestic coal price was used to estimate the coal demand formula because the coal price was influenced by the international coal market, which was highly correlated to international crude oil prices. Sub-bituminous coal demand in the industry sector (INHC) was estimated using independent variables, including industrial GDP (shown as MMINGDP) and energy consumption of the previous year. The regression test was done with RPOIL, but the use of RPOIL is not applicable because of the positive sign of coefficient of RPOIL (which is irrational because sub-bituminous coal demand will increase when price increases). A dummy variable was used for 2007 and 2014 to improve the fitting of the formula. The result of the estimated demand equation is as

follows:

$$INHC = 132.8113*CONSTANT + 0.1255E\text{-}4*MMINGDP + 0.20828*INHC(-1) - 74.9828*DUM07 - 41.8489*DUM14$$

For more details on the result of the regression analysis, see Table A-1 and Figure A-1, Appendix.

b) Electricity Demand in Industry

Due to limited national energy data, domestic electricity price for industry was not available as a price factor in the formula. Consequently, RPOIL was used instead of domestic electricity price because half of the power supply came from natural gas power plants, and the natural gas price is usually influenced by the international gas market, which is linked to international crude oil markets. Electricity demand in industry (INEL) was estimated using industrial GDP (shown as MMINGDP) and RPOIL as the independent variables. A dummy variable was used for 2009 and 2012. The result of the estimated demand equation is as follows:

$$INEL = 13.8777*CONSTANT + 0.2329E\text{-}4*MMINGDP - 0.040165*RPOIL + 75.1668*DUM0912$$

Details on the result of the regression analysis are in Table A-2 and Figure A-2, Appendix.

c) Demand for Petroleum Products in Industry

Petroleum products used in industry include diesel, fuel, and other oils. Diesel oil accounted for about 86% by 2016, fuel oil for 3%, and other oils for about 11%. Because of a data problem, diesel oil consumption in industry is estimated based on petroleum products and other fuels.

(1) Demand for petroleum products in industry (INPP) was estimated using independent variables such as industrial GDP (shown as MMINGDP), RPOIL, and energy consumption of the previous year. A dummy variable was included for 2008–2010, 2011, and 2015 to get a sound equation. The result of the estimated demand equation is

$$INPP = 689.4636*CONSTANT + 0.6668E\text{-}4*MMINGDP - 0.095630*RPOIL + 0.16475*INPP(-1) + 286.3320*DUM0810 + 432.2258*DUM11 - 1020.0*DUM15$$

The result of the regression analysis is in Table A-3 and Figure A-3, Appendix. and Diesel demand in industry (INGD) could be estimated as follows:

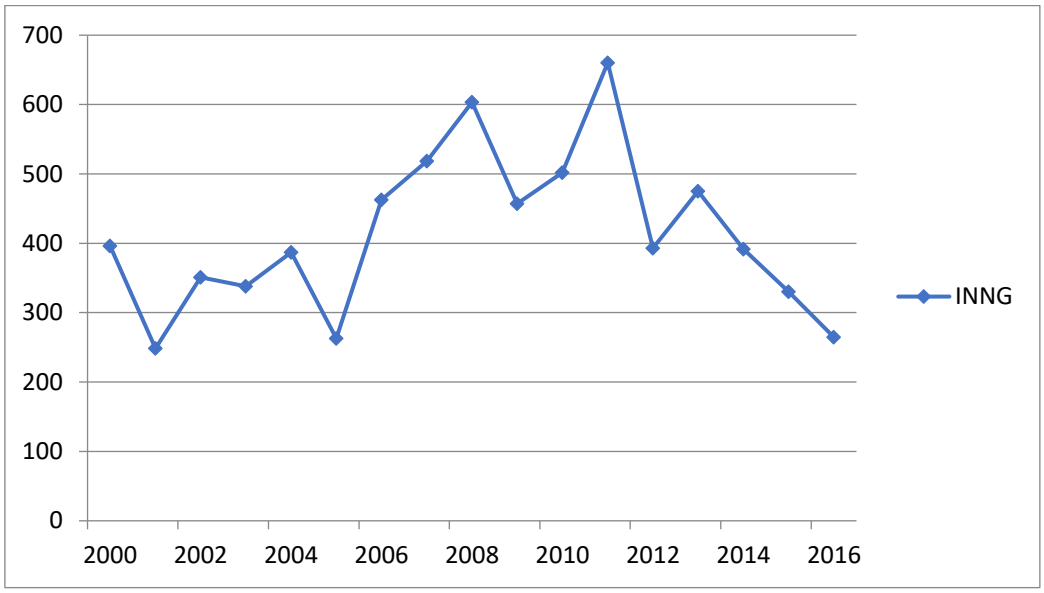
$$INGD = INPP - Fuel\ oil - Other\ oil$$

in which fuel oil and other oil demand account for a small share of total petroleum products with uncertain data, therefore we assume that the base year values (2016) will remain unchanged in the future.

d) Natural Gas Demand in Industry Sector

In the case of natural gas demand in industry (INNG), the data for 2000–2016 showed irregularity (Figure 4.1), so that the formula for INNG could not be estimated. Therefore, we assumed that INNG would keep the base year value (2016) unchanged for the future.

Figure 4.1. Natural Gas Consumption in Industry in Myanmar, 2000–2016



INNG = natural gas demand in industry.
Source: Myanmar Energy Statistics 2019.

e) Other Biomass Fuels

Other biomass fuels used in industry include fuelwood and charcoal, with the share of fuelwood at about 98.6% in 2016.

Biomass demand in industry (INBMS) is not affected by RPOIL and is not fit for regression analysis because of a data problem. Based on the historical data trend, biomass demand can be estimated to grow at 1% per year and each biomass fuel can be estimated based on the share of each fuel in the total as follows:

INBMS = Growth(1%)

Fuelwood = 0.986 INBMS*

*Charcoal = (1- 0.986) * INBMS*

2.2. Transport

Total energy demand in transport is broken down by subsector, including air, road, and rail. Most fuel consumed by transport consists of oil products, including motor gasoline, diesel oil, lubricants (or non-energy petroleum products), and jet fuel. Motor gasoline, diesel oil, and lubricants are used by road transport, whilst jet fuel is

used by aviation transport. A small part of compressed natural gas (CNG) is used for road transport.

a) Motor Gasoline Demand in Road Transport

Motor gasoline demand for road transport (RDMG) was estimated as a function of RPOIL, GDP (shown as MMGDP), and energy consumption in the previous year. A dummy variable was included for 2000–2013 to get a sound equation. The demand equation for RDMG is as follows:

$$RDMG = 139.4596*CONSTANT - 0.097656*RPOIL + 0.1612E\text{-}5*MMGDP + 0.75141*RDMG(-1) + 305.1426*DUM0013$$

The result of the regression analysis is shown in Table A-4 and Figure A-4, Appendix.

b) Lubricant Demand in Road Transport

Lubricant demand in road transport (shown as RDOOP) was estimated as a function of RPOIL and GDP (shown as MMGDP). The years for estimation were 2011–2016 to get a better equation. A dummy variable was included for 2015 to get a sound equation. The demand equation for RDOOP is as follows:

$$RDOOP = -6.9320*CONSTANT - 0.22618*RPOIL + 0.3703E\text{-}5*MMGDP + 55.8092*DUM15$$

The result of the regression analysis is shown in Table A-5 and Figure A-5, Appendix.

c) Demand for Oil Products in Road Transport

Demand for oil products in road transport (RDOIL) was estimated as a function of RPOIL, GDP (shown as MMGDP), and energy consumption in the previous year. A dummy variable was included for 2008–2013 to get a sound equation. The demand equation for RDOIL is as follows:

$$RDOIL = 781.3236*CONSTANT - 0.69850*RPOIL + 0.1038E\text{-}4*MMGDP + 0.22108*RDOIL(-1) + 260.3233*DUM0813$$

The result of the regression analysis is in Table A-6 and Figure A-6, Appendix.

d) Total Energy Demand of Road Transport

Total energy demand of road transport (RDTT) was estimated as a function of GDP per capita (GDPC), RPOIL, and the energy consumption of the previous year. A dummy variable was included for 2009 and 2012. The demand equation for RDTT is as follows:

$$RDTT = 84.5159*CONSTANT + 625.7970*GDPC - 0.80750*RPOIL + 0.35481*RDTT(-1) + 504.9038*DUM09 + 416.8222*DUM12$$

The result of the regression analysis is shown in Table A-7 and Figure A-7, Appendix.

e) Other Fuels in Road Transport

We used regression analysis to test for other fuels in road transport, but because of the limitation of statistical data, other fuels such as CNG and diesel oil (DO) were estimated based on oil products and total energy demand for road transport:

$$RDCNG = RDTT - RDOIL$$

$$RDDO = RDOIL - Gasoline - Lubricants$$

The result of the calculation in the energy model showed that DO demand by 2040 is high, with an annual average growth rate of 6.4% in 2016–2040, which is higher than for GDP in the same period. Therefore, another exogenous approach is applied as follows:

$$RDDO = GrowthFromYear(2016, 5.55\%, 2025, 2.773\%)$$

f) Aviation Transport

Aviation transport is international and domestic. Fuel demand for international aviation can be estimated based on total fuel demand for aviation transport and fuel demand for domestic aviation transport.

Total jet fuel demand of aviation transport (TTJF) was estimated using GDP (shown as MMGDP), RPOIL, and jet fuel consumption of the previous year. The estimated result of energy demand formula for TTJF is as follows:

$$TTJF = 18.9831*CONSTANT + 0.2842E\text{-}6*MMGDP - 0.016262*RPOIL + 0.88702*TTJF(-1)$$

The result of the regression analysis is in Table A-8 and Figure A-8, Appendix.

Jet fuel demand in domestic aviation transport (DAJF) was estimated as a function of GDP (shown as MMGDP), RPOIL, and the energy consumption of the previous year.

The demand equation for RDTT is as follows:

$$DAJF = 39.8634*CONSTANT - 0.041349*RPOIL + 0.2816E\text{-}6*MMGDP + 0.80633*DAJF(-1)$$

The result of the regression analysis is in Table A-9 and Figure A-9, Appendix.

2.3. Residential Sector

Energy used in the residential sector consists of electricity, liquefied petroleum gas (LPG), hard coal briquettes, and other fuel (biomass). Because of a data problem, hard coal briquettes and biomass are not fit for regression analysis; therefore, we suppose that demand for hard coal briquettes and biomass keeps their base year values (2016) unchanged for the future.

a) Electricity Demand in the Residential Sector

RPOIL was used as the price factor because of the national energy data limitation. Electricity demand in the residential sector (REEL) was estimated using independent variables, including GDP per capita (GDPC), RPOIL, and electricity consumption of the previous year. The result of the estimated demand equation is as follows:

$$REEL = 33.7965*CONSTANT + 0.1892E\text{-}3*GDPC - 0.11731*RPOIL + 0.80166*REEL(-1)$$

The result of the regression analysis is in Table A-10 Figure A-10, Appendix.

b) Liquefied Petroleum Gas Demand in the Residential Sector

LPG demand in the residential sector (RELP) was estimated using independent variables, including GDP per capita (GDPC), RPOIL, and LPG consumption of the previous year. A dummy variable was included for 2006–2010 and 2011 to improve the fitting of the equation.

The result of the estimated demand equation is as follows:

$$RELP = -4.7855*CONSTANT + 0.1449E\text{-}4*GDPC - 0.5858E\text{-}3*RPOIL + 0.23149*RELP(-1) + 8.6175*DUM0610 + 3.1833*DUM11$$

The result of the regression analysis is in Table A-11 and Figure A-11, Appendix.

2.4. Commercial Sector

Energy used in the commercial sector consists of electricity, LPG, fuel oil, natural gas, and other biomass fuels (fuelwood and charcoal). Because of a data problem, regression analysis is applicable only for electricity, and exogenous approaches are used for the remaining fuels.

a) Electricity Demand in the Commercial Sector

RPOIL was used as a price factor because of the limitation of national energy data. Electricity demand in the commercial sector (CSEL) was estimated using independent variables such as commercial GDP (shown as MMCSGDP), RPOIL, and electricity consumption of the previous year. A dummy was used for 2014. The result of the estimated demand equation is as follows:

*COMEL = -26.0884*CONSTANT + 0.4849E-5*MMCSGDP - 0.025305*RPOIL + 0.62662*COMEL(-1) + 31.6028*DUM14*

The result of the regression analysis is in Table A-12 and Figure A-12, Appendix.

b) Biomass Demand in the Commercial Sector

Biomass demand in the commercial sector (COMBMS) is not affected by RPOIL and is not fit for regression analysis because of a data problem. Based on historical data, we can estimate the share of each fuel (fuelwood and charcoal) in total biomass fuels used in the commercial sector. Assuming that the share of each fuel is maintained in the coming years, we can estimate the demand of biomass fuels as follows:

COMBMS = Growth(0,1%)

COMCHC = COMCHCSH (-1) COMBMS*

COMFWD = (1- COMCHCSH(-1)) COMBMS*

Where:

COMCHC = Charcoal demand in the commercial sector

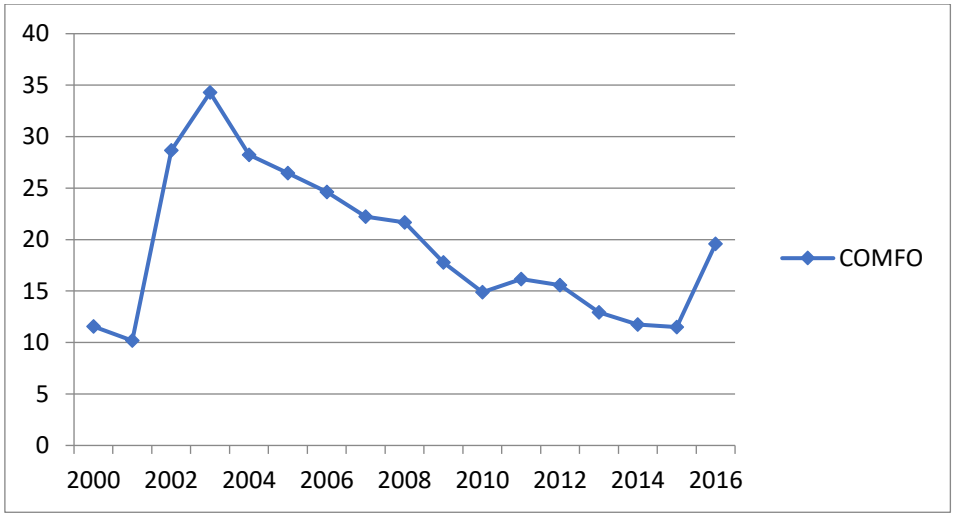
COMCHCSH = Charcoal share in the total biomass fuels

COMFWD = Fuelwood demand in the commercial sector

c) Fuel Oil Demand in the Commercial Sector

In the case of fuel oil in the commercial sector (COMFO), the data for 2000–2015 showed irregularity (Figure 4.2), so that the formula for diesel oil could not be estimated.

Figure 4.2. Fuel Oil Consumption in the Commercial Sector in Myanmar, 2000–2016



COMFO = commercial sector.
Source: Myanmar Energy Statistics 2019.

In this case, we assumed that fuel oil demand is maintained in the coming years as follows:

COMFO = COMFO(-1)

d) Liquefied Petroleum Gas and Natural Gas Demand in the Commercial Sector

LPG (COMLP) and natural gas (COMNG) have been used in the commercial sector for several years. Therefore, the regression analysis is not applicable because of insufficient data, and other exogenous approaches such as growth as commercial GDP (shown as MMCSGDP) were used as follows:

COMLP = GrowthAs(MMCSGDP)

COMLP = GrowthAs(MMCSGDP)

2.5. Other Key Variables

Aside from the main variables such as GDP, RPOIL, amongst others, other related key variables worked as the main drivers for energy demand projection, including GDP deflator or price index for GDP (PGDP) and sectoral GDP. However, these future variables are still lacking because of the limitation of data. Thus, in this study, these functions are estimated based on relationships amongst other related available variables by regression analysis.

a) Gross Domestic Product Deflator

The crude oil price is clearly tied to economic activity and inflation. If the crude oil price increases, the consumer price index also increases. Therefore, GDP deflator (PGDP) was estimated as a function of (POILJ) and PGDP of the previous year as follows:

$$PGDP = 2.1175*CONSTANT + 0.0084665*RPOIL + 0.97967*PGDP(-1)$$

The result of the regression analysis is shown in PGDP = *2.1175*CONSTANT + 0.0084665*RPOIL + 0.97967*PGDP(-1)*

See Table A-13 and Figure A-13, Appendix.

b) Industrial Gross Domestic Product

Industrial GDP (shown as MMINGDP) is the main component and contribution to GDP growth. Thus, MMINGDP was estimated as a function of GDP (shown as MMGDP) and MMINGDP of the previous year with the equation as follows:

$$MMINGDP = -1566795*CONSTANT + 0.14423*MMGDP + 0.67479*MMINGDP(-1)$$

The result of the regression analysis is in Table A-14 and Figure A-14, Appendix.

c) Commercial Gross Domestic Product

Like industry GDP, commercial GDP (shown as MCSGDP) was estimated as a function of GDP and MCSGDP of the previous year. The estimated equation is as follows:

$$MCSGDP = -138528.5*CONSTANT + 0.085424*MMGDP + 0.86841*MCSGDP(-1)$$

The result of the regression analysis is in Table A-15 and Figure A-15, Appendix.