Lab 4: Peak Oil

In 1956, **M. King Hubbert** observed that annual production of fossil fuels (coal, oil, and natural gas) in a given geographic region "starts slowly and then rises more steeply until finally an inflection point is reached after which it becomes concave downward" (p. 6). Since the total amount of fossil fuels that can be easily extracted is finite, Hubbert reasoned that the annual production of each would necessarily reach maximum at some point in the future.

In this lab, we will model the production of crude oil in the United States and the world using a logistic model

$$P = \frac{dQ}{dt} = rQ\left(1 - \frac{Q}{M}\right)$$

where $P = dQ/dt$ is the amount of crude oil produced each year and Q is the cumulative amount of crude oil produced since 1859. We will use the fact that the relative growth rate

$$\frac{\frac{dQ}{dt}}{Q} = r\left(1 - \frac{Q}{M}\right) = r - \left(\frac{r}{M}\right)Q$$

is a linear function of Q to estimate the natural growth rate r and the carrying capacity M. We will then use our model to predict "peak oil."

U.S. Oil Production (1859–1956)

Hubbert estimated the total amount of recoverable crude oil in the United States to be 150 billion barrels and predicted that the annual production of crude oil in the United States would peak in about 1965. He also considered an "optimistic" scenario in which the ultimate amount of recoverable crude oil in the United States is 200 billion barrels, in which case he predicted that annual production would peak in 1970.

1. Open the Excel spreadsheet `Peak Oil.xlsx` and click on the sheet *US Oil Production (1859–1956)*. Column B shows the amount of crude oil produced in the United States from 1900–1956. Cell C2 contains an estimate of the total amount of crude oil produced in the United States since it was discovered in 1859.

2. We can keep a running total the cumulative amount of oil produced in the United States by adding the current year's production to the previous total. Click on the cell C3 and inspect the formula contained therein. Now complete column C using the `Fill Down` command.

3. Calculate the relative growth rate of U.S. crude oil production in each year from 1900 to 1956.

4. Create a scatter plot of the relative growth rate versus the cumulative production for 1900–1956.

5. Control-click (right-click on Microsoft Windows) on a data point in your scatter plot and select `Add Trendline...`.

6. Under *Options* in the Format Trendline dialog box, check `Display equation on chart`.

7. Calculate the y-intercept of the trendline using the formula `=INTERCEPT(D5:D61,C5:C61)`.

8. Calculate the slope of the trendline using the formula `=SLOPE(D5:D61,C5:C61)`.

9. Use the y-intercept and the slope of the trendline to estimate r and M.

10. Notice that the relative growth rate is volatile when Q is small. (Why?) To prevent this volatility from affecting our estimates of r and M, repeat Steps 4 through 9 excluding the years prior to 1930.

11. Show that annual crude oil production will peak when the cumulative amount of crude oil produced is half the total amount of recoverable oil. [Hint: Let $P = dQ/dt$, then maximize P using dP/dQ.]

12. Use the following solution to the logistic equation

$$Q = \frac{M}{1 + Ae^{-rt}} \qquad A = \frac{M - Q_0}{Q_0},$$

to predict when the annual production of crude oil in the United States will peak. [Hint: Let $t = 0$ correspond to the year 1930.]

U.S. Oil Production (1859–2005)

1. Click on the sheet *US Oil Production (1859–2005)*.

2. When did annual crude oil production peak in the United States?

3. Fill in the missing data in columns C and D.

4. Create scatter plots of the relative growth rate versus cumulative production for the periods 1900–2005 and 1930–2005.

5. Add trendlines to your scatter plots and re-estimate M using the data from 1930–2005.

World Oil Production (1960–2005)

Now we will repeat our analysis using world oil production data. (Note that world oil production data is not as reliable as the data for the United States.)

1. Click on the sheet *World Oil Production*.

2. Fill in columns C and D.

3. Create a scatter plot of the relative growth rate versus cumulative oil production in the entire world.

4. Slowly adjust the data range of your scatter plot to eliminate any noisy early data. Stop once the data look approximately linear. What years did you include?

5. Add a trendline to your scatter plot.

6. Estimate r and M as you did for U.S. oil production. How does M compare to Hubbert's estimate of 1250 billion barrels for total world oil reserves?

7. Predict when world crude oil production will reach its maximum. How does your prediction compare to Hubbert's prediction that world crude oil production will peak "at about the year 2000" (p. 22)?