Appendix C Cost Model Documentation:

Cost Model Documentation: http://dahl.mines.edu/B&D18spr/B&D18AppxC.pdf

Cost Model: http://dahl.mines.edu/ B&D18spr/B&D18AppxC.xlsx

To Accompany

Bai, Yang and Carol A. Dahl (forthcoming 2018) Evaluating the management of U.S. strategic petroleum reserve during oil disruptions. *Energy Policy*, Special Issue Oil Supply Disruptions, U.S. Economic Activity and Oil Security.

SPR cost in the model consists of cost of the oil (c^{oil}), the cost of the facility and expansion ($c^{fac\ \&\ exp}$), the cost of maintenance (c^{man}), and the welfare cost (reduction of consumer surplus minus the increase in producer surplus) resulting from the price increase from oil purchases for the SPR (c^{w}). Costs include carrying costs at real interest rate r_t from 1976-2014 (year N). Total cost of oil is computed using equation (1) in the paper:

$$c^{oil} = \sum_{t=1976}^{N} \left(c_t^{oil} \prod_{t}^{N} (1+r_t) \right) - C_N^{oil} \qquad (1)$$

We describe the computations for the base case first with all cost computations contained in B&D18AppxC.xlsx. The source for the historical information used for the computations are given at the tops of the column in the excel file. We chose the import price because about 80% of the SPR crude comes from imports, it is the cost of a marginal barrel of crude oil in the U.S., it is available as a monthly and annual series over the whole valuation period and we can use it as a proxy for world price. The cost of oil is computed by taking the nominal import price of crude oil in column B, times the purchases/sales of oil computed in column D, times the factor needed to inflate prices to 2014 values in column R, times the factor to add in the interest rate in column AD with the annual result in column AK. The sum of these crude oil costs is computed in cell AK47. The value of oil in the SPR in 2014 in cell G53 is computed from the stock of SPR oil in 2014 given in cell C45 (repeated in C53) times the import price in B45 which is repeated in E53. The total computed cost of oil from equation (1) above is given in cell G54, which is converted from thousands to millions in A57. The values in the red font in I56-I59 can be changed to do sensitivity tests on interest rate, end price of oil, years to depreciate the SPR facility, and whether or not to reduce costs by lease revenues given in column K.

To compute the cost of facilities, substituting equation (3) into equation (4). which yields:

$$C_t^{fac\ \&\ exp} = \sum_{t=1}^{N} \left[c_t^{fac\ \&\ exp} \prod_{i=t}^{N} (1+r_i) - \frac{c_t^{fac\ \&\ exp}}{M} \left[(1+r_t) + \prod_{i=t}^{t+1} (1+r_i) + \cdots + \prod_{i=t}^{t+M} (1+r_i) \right] \right] \quad (3 \rightarrow 4)$$

The costs the facilities and expansions are given in column G and H. They come from federal government appropriations given in EIA (2016). They are converted from fiscal year (October 1-September 30 to calendar years by allocating one-fourth of the previous year appropriation plus three fourths of current year appropriations and then converted to 2014 values by multiplying by column R with the resulting values in columns V and W with their sum in column X. Capital costs are added into each of these three values by multiplying column AD with the result in AL, AM, and AN. The remaining non-depreciated value is given in column AQ. Total facilities and expansion summed over the whole evaluation period including carrying cost is in cell AN47. Remaining non-depreciated value of the asset is summed in cell AQ47. The total cost of the facilities and expansions is computed by taking the total cost in cell AN47 and subtracting the estimate of the remaining value of the assets in cell AQ47 and changed from thousands of 2014 dollars to millions of 2014 dollars in cell B57.

Management cost is computed by equation 5 in the paper:

$$c^{man} = \sum_{t=1976}^{N} \left(c_t^{man} \prod_{t}^{N} (1 + r_t) \right) \tag{5}$$

The annual nominal appropriated management costs by fiscal year are given in column I. In column Y, they are converted from fiscal year to calendar year, calendar year lease revenues in column K are subtracted, and the difference is converted to 2014 values by multiplying by column R. Interest costs are added in by multiplying column Y by column AD with the results in column AO. These costs are summed across time in cell AO47 and converted from thousands to millions in cell C57.

A last included cost of the SPR is the welfare loss from market price increases from U.S. SPR crude oil purchases during non-disrupted periods, which we describe for linear world demand and supply as follows. Starting with the demand and supply (equations (6) and (7) in the paper), we compute the slopes of these functions in each non-disruption year *t* by normalizing around the real world actual price taken to be the U.S. import price (p_t in column AU) and world oil consumption or production given in column AW (D_t^0) and AX (S_t^0) using the selected demand and supply price elasticities in columns BD and BE and equations (11):

$$a_t = \sigma \frac{D_t^0}{p_t} \text{ and } b_t = \varepsilon \frac{S_t^0}{p_t} \tag{11}$$

The 0 superscript reminds us we are in non-disruption years. The oil production and consumption numbers include natural gas liquids as these were the only series we could get complete numbers for the U.S. and the World for annual and monthly data for the whole model life (1977-2014). Crude price (p_{t1}) purged of SPR purchases(+)/sales(-)(q_t^{SPR}) is computed from observed price p_{t2} in column AU by rearranging equation 10 in the paper to equation (10)' below.

$$p_{t1} = p_{t2} + \frac{q_t^{SPR}}{a_t - b_t} \tag{10}'$$

The spr purchases/sales in the above equation are computed from spr stock changes in column BB and converted to barrels per day in column BA. During disruption years only the purchases during the non-disruption time are included. These amounts are highlighted in green in column BB, a_t and b_t are computed in cells, and p_{t1} (world price purged of SPR purchases) is computed in column BH. Crude price (p_{t1}) purged of SPR purchases(+)/sales(-)(q_t^{SPR}) is computed from observed price p_{t2} in column AU by rearranging equation 10 in the paper to equation (10)' below in column BH:

$$p_{t1} = p_{t2} + \frac{q_t^{SPR}}{a_t - b_t} \tag{10}'$$

Next the same computations are used to create U.S. demand and supply parameters on price again using world price in column AU, but now normalizing around U. S. consumption including natural gas liquids in Column AY and U.S. production including natural gas liquids in column AZ. The coefficients for a linear demand curve and a log linear supply curve with the assumed U.S. demand and supply elasticities in columns BJ and BK are given in columns BK to BN. The price change from SPR activity from price p_{t1} (no spr activity) to observed price (p_{t2}) is given in column BP. The welfare change from the price change is computed in column BO from the integral in equation (12) in the paper.

$$c_t^w = \int_{p_{t1}}^{p_{t2}} \left[D_{tus}(p) - S_{tus}(p) \right] dp \tag{12}$$

These costs in $1000 per day in column BN are adjusted for the interest rate in column BR by multiplying by column AD. They are summed over the program in cell BR46, and converted to annual values in

millions of dollars in cell BR48 with the comparable value including no interest payments in cell B46 and repeated in E131. The overall cost excluding and including the welfare costs are in cells D57 and F57.

Cells in red font allow for sensitivity testing. You can change the end value of oil in cell E53. You can change the interest rate series in cell H36 to D for the risk free rate, G for the corporate AAA bond rate, H for the 1st quartile of the risk free rate, and I for the 3nd quartile of the risk free rate. You can change the depreciation period for the facility in cell H57 and if you don't want to deduct lease revenues from cost make cell H57 equal to zero no 1. We tried two crude costs. We computed the cost of crude from price and changes in the reserve stocks in column T, which we think is the more accurate representation. To use these values make cell H59 equal to 1. The other value was total government appropriations for crude stocks in column U, which are not always spent. To use this value change cell H59 to 2. World short run demand and supply elasticities can be changed in cells BC7 and BD7. U.S. short run demand and supply elasticities can be changed in cells BI7 and BJ7. The model is set up to use the same elasticities every year. You can override this assumption by entering different values for different year.

**********Last Modified February 14, 2018**********