Appendix D: Measuring Benefits of the SPR During Disruptions

Benefit Model Documentation: http://dahl.mines.edu/B&D18spr/B&D18AppxD.pdf

Cost Model: http://dahl.mines.edu/ B&D18spr/B&D18AppxD.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.

We measure two benefits of disruptions in three worksheets in the model workbook (B&D18AppxD.xlsx), one for each disruption: Bfit90-91, Bfit05, Bfit11. All cell references given refer to these three worksheets unless otherwise indicated. The welfare benefits including interest costs are computed using equation (16) in the paper with the definition of b_t^w substituted in from equation (15), which yields our welfare benefits as:

$$b^w = \sum_{t \in td}\left(b_t^w \prod_{i=t}^{2014}(1+r_i)\right) = \sum_{t \in td}\left(\left[\int_{p_{t2}}^{p_{t1}}\left[D_{tus}(p) - S_{tus}(p)\right]dp\right]\prod_{i=t}^{2014}(1+r_i)\right) \qquad (15\text{-}16)$$

In the above equation, p_{t2} is the observed oil price during the disruption It is given in cell C7, computed from monthly data in worksheet Tm cell Z182, and repeated in cell C21. Tm contains monthly data we used for benefit computations (U.S. and world production and consumption numbers, crude price, and U.S. GDP). It includes the data series chosen as well as other data series considered. Crude price (p_{t1}) purged of OECD government and private sector stock changes is computed from observed price p_{t2} in cell C21 but replacing U.S. SPR stock changes with total OECD government and private sector changes to get equation (10') below.

$$p_{t1} = p_{t2} + \frac{q_t^{SPR} + q_t^o + q_t^{pr}}{a_t - b_t} \qquad (10')$$

The oil inventory changes are developed in Appendix B (http:\\dahl.mines.edu\B&D18spr\B&D18AppxB.pdf) and included in worksheet T1 in the Benefit worksheet in this appendix (http:\\dahl.mines.edu\B&D18spr\B&D18AppxD.xlsx). The U.S. strategic stock changes (q_t^{SPR}) are averaged to millions of barrels per day in cell B12, government stock changes for the rest of the OECD (q_t^o) are computed in cell F14, OECD private sector oil and oil product stock changes for the OECD (q_t^{pr}) are computed in cell G15, while their seasonally adjusted counter parts are computed in cell H15. The denominator in the above equation ($a_t - b_t$) are the slopes of world demand and supply equations. They are computed in D18 and D20, by creating linear demand and supply equations using the chosen world demand and supply disruption price elasticities in cells C15 and C16. In the base case, these are chosen to be σ = -0.02 and ε = 0.025, respectively. The demand equations are normalized through observed price and quantity demanded in cells D7 and D8 and supply is normalized through observed price and estimated production. If disruption years are the set td, then quantity supplied (S_t) during a disruption at time $t \in td$ is computed by rearranging equation (20) in the paper:

$$d_t + a_t p_t = s_t + b_t p_t - \lambda_t - \left(q_t^{SPR} + q_t^o + q_t^{pr}\right) = D_t = S_t - \lambda_t - \left(q_t^{SPR} + q_t^o + q_t^{pr}\right) \rightarrow \qquad (20)$$

$$D_t + \lambda_t + q_t^{SPR} + q_t^o + q_t^{pr} = S_t$$

S_t is computed in cell C9. Then the slopes for supply and demand equations are computed in cells D18 and D10 from equations (11) in the paper.

$$a_{t\in td} = \sigma \frac{D_t}{p_t} \text{ and } b_{t\in td} = \varepsilon \frac{S_t}{p_t} \tag{11}$$

The slopes of world demand and supply in equation (11) are computed in cells D18 and D20. Although we don't need them for our other computation, we also compute the intercepts for world demand and supply equations in cells C18 and C20. Armed with these slopes, we can compute the price without the stock changes in cell C22 using equations (10') and without the stock changes and disruption in C23. We compute the price change for 4 cases, which we can chose in cell H2. If we chose case E, we are removing only the U.S. government stock change. If we choose F, we are removing all OECD government stock changes including both government oil and oil product stocks. If we choose F, we are removing all OECD government stock changes plus OECD private stock changes. If we choose G, we are removing all OECD government stock changes plus seasonally adjusted OECD private stock changes. Having computed the price change we are soon ready to measure the first benefit from the reduced price. The welfare benefits of the stock drawdown from equation (15-16) is computed by integrating U.S. demand minus U.S. supply and adding interest costs. However, we still need U.S, demand and supply equations.

We create U.S. demand and supply parameters around observed price given in cell C7, but now normalize around U.S. consumption including natural gas liquids in C30 and U.S. production including natural gas liquids in cell C31. U.S. production and consumption numbers are obtained by averaging production and consumption over the disruption months in worksheet Tm columns F and J. The coefficients for a linear demand curve and a log linear supply curve are computed in cells C34 to D36 using the the assumed U.S. demand and supply elasticities in cells C28 and C29. Next, we compute the integral in equation (15) in the paper in cell C37, which is measured in millions of dollars a day. Multiple by days in cell C40 and accumulate interest on these net benefits in cell C41. Convert from millions to billions of 2014 $ in cell G7.

The second benefit is the reduction in macro disruption costs, which is observed GDP during the disruption minus an estimate of what GDP would have been without the stock change given in equation (17) below from the paper.

$$b_t^g = GDP_{t2} - GDP_{t1} = GDP_{t2}\left[1-\left(\frac{P_{t1}}{P_{t2}}\right)^e\right] \rightarrow GDP_{t1} = \left(\frac{P_{t1}}{P_{t2}}\right)^e GDP_{t2} \tag{17}$$

GDP_{t2} is computed by averaging real GDP over the quarters that include disruption months in worksheet Tm column AG and recorded in cell C24. GDP_{t1} is computed as in equation (17) in cell C26 using the assumed GDP disruption elasticity in C25. Cell C27 contains the macro benefit, which is the GDP differential adjusted for interest payments as computed by equation (18) in the paper.

$$b^g = \sum_{t\in td}\left(\left[GDP_{t2} - GDP_{t1}\right]\prod_{i=t}^{2014}\left(1+r_i\right)\right) \tag{18}$$

This value in billions of 2014 $ is also shown in cell G9. Summing the welfare benefits and the macro disruption benefits of stock drawdowns gives the total benefit per disruption in cell G10. The values reported in the paper in Table 4-6 are given in cells G3-G10.

Sensitivity tests can be conducted by changing the values in red font. World demand and supply price elasticities can be changed in cells C15-C16 in each sheet. GDP disruption price elasticity can be changed in cell C25. U.S. demand and supply price elasticities can be changed in cells C28 and C29. The interest rate series can be changed in cell A43. The drawdown cases can be changed in cell H1. E evaluates benefits from only the U.S. government drawdown. F evaluates benefits from all OECD government drawdowns. G evaluates OECD government stock changes plus OECD private stock changes. H evaluates all OECD government stock changes plus seasonally adjusted OECD private stock changes.

**********************Last modified February 14, 2018************************************