State Tax Policy and Oil Production:

Discussion by Stephen Salant

Discrete-Time Version

$$\text{Max}_{x_t, q_t, w_t, R_t \geq 0} \sum_{t=1}^{T} \beta^{t-1}[pq_t - c(q_t, R_t) - k(w_t)]$$

subject to:

$$\theta_t : \quad R_{t+1} \leq R_t + f(\overbrace{x_t}^{-}, \overbrace{w_t}^{+}) - q_t, \text{ for } t = 1,\dots,T$$

$$\lambda_t : \quad x_{t+1} = x_t + w_t \text{ for } t=1,\dots,T$$

$$\text{where } R_1 = \bar{R} \text{ and } x_1 = \bar{x}.$$

Sources of Confusion

- Early draft but very promising
- Meaning of x_t
- Sign of λ_t
- Price-taking does not require that price is unchanging over time (why not historical series or forecast of future?).
- Is $C_{qR}=0$ as in assumptions or <0 as in simulations?

Reformulation Without x_t

$$\text{Max}_{x_t, q_t, w_t, x_t, R_t \geq 0} \sum_{t=1}^{T} \beta^{t-1} [pq_t - c(q_t, R_t) - k(w_t)]$$

subject to:

$$\theta_t : \qquad R_{t+1} \leq R_t + f(\bar{x} + \sum_{j=1}^{t-1} w_j, w_t) - q_t, \text{for } t = 1, \ldots, T$$

$$\text{where } R_1 = \bar{R}.$$

Optimal Feet to Drill at t

- Marginal Cost=Marginal Benefit

$$\beta^{t-1} k'(w_t) =$$

$$\theta_t f_w(\bar{x} + \sum_{j=1}^{t-1} w_j, w_t) + \underbrace{\sum_{i=t+1}^{T} \theta_i f_x(\bar{x} + \sum_{j=1}^{i-1} w_j, w_t)}_{\text{Negative Consequence of Drilling Today}}$$

Summary of Calibration

$$C = 458.1\, q^{2.86} R^{-1.86}$$

$$f = 28.78\, w^{.95} e^{-000457\, x}$$

$$k(w) = 1.23\, w^{2}$$

$$T = 150,\ r{=}4\%,\ p{=}\$70 \text{ per barrel},\ \bar{R}{=}20\times10^{9} \text{ barrels},$$

$$\bar{x} = 2\times10^{9} \text{ feet}$$

Presentation of Consequences of Tax Policies

$$\text{Max}_{x_t, q_t, w_t, R_t \geq 0} \sum_{t=1}^{T} \beta^{t-1}[\alpha_p p q_t - \alpha_c c(q_t, R_t) - \alpha_D k(w_t)]$$

Re−scaling will not affect the location of the optimum:

$$\text{Max}_{x_t, q_t, w_t, R_t \geq 0} \sum_{t=1}^{T} \beta^{t-1}[\hat{\alpha}_p p q_t - \hat{\alpha}_c c(q_t, R_t) - 1 \bullet k(w_t)]$$

where $\hat{\alpha}_p = \frac{\alpha_p}{\alpha_D}$ and $\hat{\alpha}_c = \frac{\alpha_c}{\alpha_D}$

- In $(\hat{\alpha}_p, \hat{\alpha}_c)$ space one could graphically summarize the consequences of the tax policies:
  - Iso initial production, drilling
  - Iso cumulative production, drilling

Presentation of Consequences of Tax Policies

Model	$\hat{\alpha}_p$	$\hat{\alpha}_c$
A. No Tax	1	1
B. Low Tax	$\frac{.72}{.92} = .78$	$\frac{.90}{.92} = .98$
C. High Tax	$\frac{.62}{.92} = .67$	$\frac{.90}{.92} = .98$
D. Drilling Subsidy	$\frac{.62}{.72} = .86$	$\frac{.90}{.72} = 1.25$

Insensitivity to Tax Changes

- In the analytical section, cost function is assumed to have

$$c_q > 0, c_{qq} > 0, c_R < 0, c_{RR} > 0$$

- But in all the simulations, the marginal cost of extraction (c_q) steepens as q becomes larger while the marginal cost of drilling $(k'(w))$ increases linearly.
- The assumptions in the analytical section permit each curve to flatten at higher rates of extraction and drilling.

An Observation and a Suggestion

- The insensitivity of current extraction to tax changes is a consequence of the curvature of the marginal-cost functions adopted in the simulations combined with the assumption that prices never vary over time. The insensitivity is not, as asserted, a consequence of the structure of the model.

- If actual extraction has varied little historically despite wild swings in the oil price, the authors could instead justify the curvature assumptions in their simulations on the basis of this historical experience.