The Effects of Royalties on Oil and Gas Production

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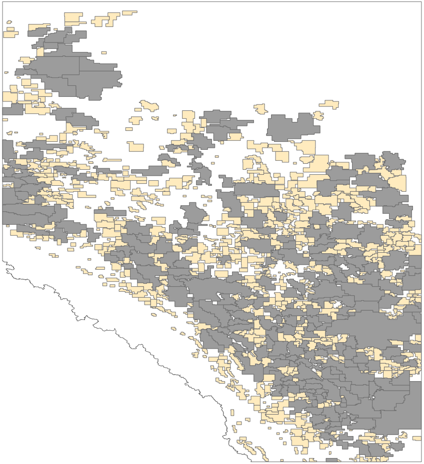
Objective

- Understand the effect royalties have on oil and gas production:
    1. Tilting?
    2. High-grading?
    3. Government revenue?
    4. Exploration rates?
    5. Geographic distribution of exploration?
- In this presentation, I focus on exploration.

How?

- Estimate a structural model of oil and gas production that includes both exploration and extraction.
- Construct a firm-level panel consisting of decisions made 700 firms concerning over 350,000 wells.
  1. How much to explore.
  2. Where to explore.
  3. extraction rates—monthly volumes from 1975 to 2006.
- Construct a pool-level panel of over 40,000 pools.
  1. Construct Reserves estimates for each firm.
  2. Estimate field specific costs.

Idea



Firm's Decision Problem

- The firm maximizes discounted future profits,

$$\max_{q_t, w_t} \mathrm{E}\left[\sum_{t=0}^{\infty} \beta^t \left[\tilde{p}_t q_t - c(q_t, R_t) - d(w_t)\right] \middle| \Omega_t\right]$$

subject to 2 transition equations:

1. Reserves:
$$R_{t+1} = (R_t - q_t) + f(w_t, W_t).$$
2. Wells:
$$W_{t+1} = W_t + w_t.$$

and a resource constraint

1. $$q_t \leq R_t.$$

Bellman Equation

- The corresponding Bellman equation is

$$v(p, R, W) = \max_{q,w} \left\{ \tilde{p}q - c(q, R) - d(w) + \beta \mathrm{E}[v(p', R', W')|\Omega_t] \right\}$$

- Subject to the law of motion for reserves,

$$R' = (R - q) + f(w, W),$$

and the law of motion for the total number of wells drilled,

$$W' = W + w.$$

Euler Equations

- Euler equation for extraction:

$$\tilde{p} - \frac{\partial c(q, R)}{\partial q} = \beta \mathrm{E}\left[\left(\tilde{p}' - \frac{\partial c(q', R')}{\partial q'}\right) - \frac{\partial c(q', R')}{\partial R'}\middle|\Omega_t\right].$$

Euler Equations

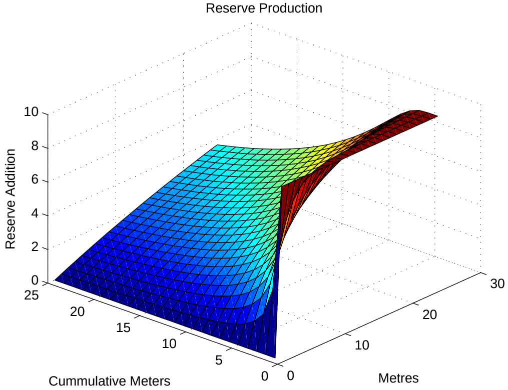
- Euler equation for reserve production

$$\left(\tilde{p} - \frac{\partial c(q,R)}{\partial q}\right)\frac{\partial f(w,W)}{\partial w} - \frac{\partial d(w)}{\partial w}$$
$$= \beta \mathrm{E}\left[\frac{\partial f(w',W')}{\partial w'}\left(\tilde{p}' - \frac{\partial c(q',R')}{\partial q'}\right) - \frac{\partial d(w')}{\partial w'}\middle|\Omega_t\right].$$

Empirical Model

- Reserve Production Function:

$$f(w_t, W_t) = \Gamma \left[1 - \exp\left(-\gamma \frac{w_t}{1 + W_t} \right) \right]$$



Empirical Model

- Lifting Costs:

$$c(q_t) = \alpha_0 q_t + \alpha_1 \frac{1}{2} q_t^2 + \alpha_2 R_t.$$

- Drilling Costs:

$$d(w_t) = \tau_1 w_t + \frac{1}{2} \tau_2 w_t^2.$$

- Prices:

$$p_{t+1} = a_0 + a_1 p_t + u_t \qquad u_t \sim N(0, \sigma^2)$$

Empirical Problem

- The empirical problem is to estimate the parameter vector for each of the K fields:

$$\mathbf{\Phi} = [\Gamma, \gamma, \tau_1, \tau_2, \alpha_0, \alpha_1, \alpha_2, a_0, a_1, \sigma^2]$$

Estimator

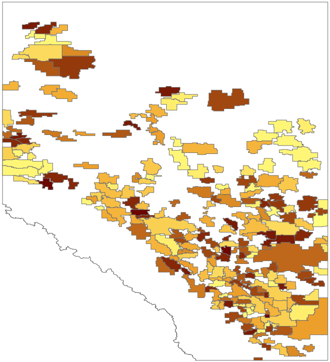
- The GMM estimates of $\mathbf{\Phi}$ are obtained by choosing $\tilde{\mathbf{\Phi}}$ that minimizes the vector function

$$\mathbf{S} = \left[\sum_{\mathbf{i=1}}^{\mathbf{N}} \mathbf{z_i'M_i}(\mathbf{X};\tilde{\mathbf{\Phi}})\right]' \tilde{\mathbf{\Omega}}_{\mathbf{i}} \left[\sum_{\mathbf{1=1}}^{\mathbf{N}} \mathbf{z_i'M_t}(\mathbf{X};\tilde{\mathbf{\Phi}})\right]$$

where $\tilde{\mathbf{\Omega}}$ is a weighting matrix and $M_t(X;\tilde{\mathbf{\Phi}})$ is

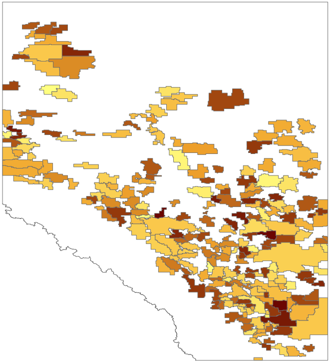
$$\mathbf{M}_i(\mathbf{X}_t;\mathbf{\Phi}) = \begin{pmatrix} \mathbf{m}_{1t}(\mathbf{X}_t;\mathbf{\Phi}) & \mathbf{0} \\ \mathbf{0} & \mathbf{m}_{2t}(\mathbf{X}_t;\mathbf{\Phi}) \end{pmatrix}.$$

Preliminary Results: Lifting Costs



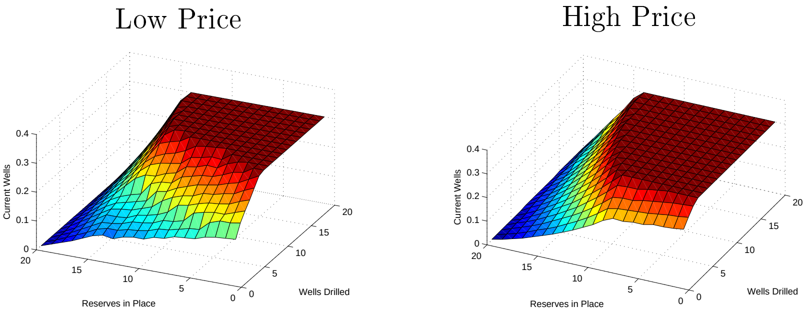
- Map illustrating estimated lifting costs evaluated at field-specific means

Preliminary Results: Drilling Costs

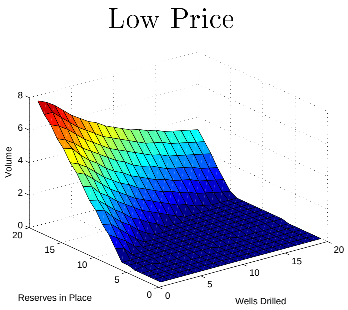


- Map illustrating estimated drilling costs evaluated at field-specific means

Policy Functions: Exploration Wells



Policy Functions: Volume



Policy Simulation: Mean of the Parameter Estimates

Percent Increase	Number of Exp. Wells	Percentage Change
0	12663	0
1	12575	-0.88
2	12444	-1.73
4	11848	-6.44
6	11382	-10.12
8	11103	-12.32
10	11008	-13.07

Policy Simulation: Low Cost and High Volume Fields

Percent Increase	Number of Exp. Wells	Percentage Change
0	24212	0
1	22999	-5.01
2	24932	2.97
4	22575	-6.76
6	22667	-6.38
8	22635	-6.51
10	22316	-7.83

Policy Simulation: High Cost and Low Volume Fields

Percent Increase	Number of Exp. Wells	Percentage Change
0	507	0
1	486	-4.14
2	508	0.20
4	516	1.78
6	541	6.71
8	488	-3.75
10	512	0.99

Policy Simulation: High Reserve Production Fields (high γ and Γ)

Percent Increase	Number of Exp. Wells	Percentage Change
0	15582	0
1	15580	0
2	15562	-0.001
4	15529	-0.003
6	15498	-0.005
8	15458	-0.008
10	15312	-0.017

Thanks for your attention