Environmental bonds and public liability for resource extraction site cleanup

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Environmental consequences from resource extraction

(a) Mount Polley, Mine tailings pond dam failure dam, B.C., Canada, 2014

(b) Orphan oil well, Alberta, Canada, 2023

Sources:(a) Dirk Meissner, CBC, *Mount Polley mine disaster 5 years later; emotions, accountability unresolved*, Aug 4 2019. Image: Jonathan Hayward/Canadian Press. (b) Emma Graney,Catastrophe looms without overhaul of Alberta's inactive oil and gas well rules, report says Globe and Mail. Image: Geoff Robins/ Getty Images

Inadequate cleanup after resource extraction activities

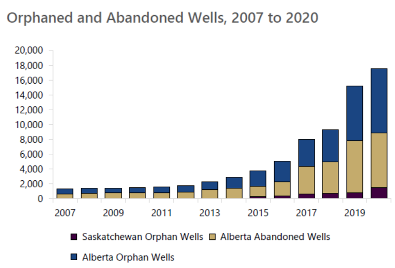
- **Legal obligation** for firms to manage extraction activities so as not to harm the environment and to clean up their sites once operations are terminated (strict liability).
- Some form of **financial surety** is commonly required - such as surety bonds, cash deposits, letters of credit etc.
- **Regulations are often inadequate** and/or not enforced. Financial surety is inadequate.
- **Firms go bankrupt** leaving large cleanup liabilities for government, or just delay cleanup for many years.
- **Environmental damages** arising from unremediated sites.

Huge inventory of orphaned or inactive oil and gas wells

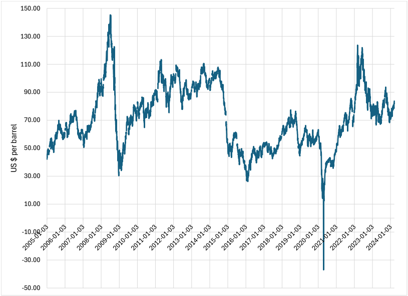
- A problem in Canada and the U.S.
- **Cost for cleanup** of wells with no solvent owner in Canada estimated to reach C$1.1 billion by 2025.*
  - Ignores the cost of inactive/plugged wells.
  - Does not include full cost of cleanup. **Cleanup costs are highly variable.**
- **Environmental consequences.** If improperly plugged, non-producing wells may contaminate water supplies, degrade ecosystems and emit methane and other air pollutants.
- Newspaper headline from October 2023 (Globe and Mail). **"Catastrophe looms without overhaul of Alberta's inactive oil and gas well rules, report says"**

*Canada Parliamentary Budget Office, 2022

Wells with no solvent owner and oil prices



(c) Wells in Alberta and Saskatchewan with no solvent owner, PBO (2022)



(d) WTI crude oil price, US$/bbl. (US Federal Reserve Economic Data) .

How to regulate natural resource extraction projects?

Goal is to maximize the value of the resource asset **to society** and ensure proper cleanup is done.

- Develop a stylized model of a firm's operating decisions for a gas well. (A stochastic dynamic optimal control model).
- Implement a numerical procedure to solve for the firm's optimal decisions (optimal controls) and value of the well to the firm.
- Use these optimal controls in Monte Carlo analysis to determine the value of the well to the government.
- Total value to society = value to the firm + value to government

How to regulate natural resource extraction projects?

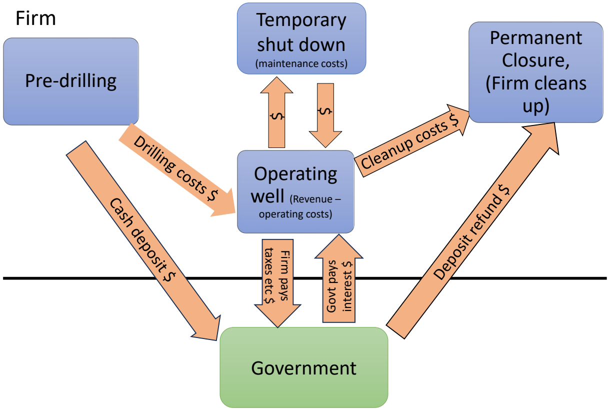
Resource value comes from:

- Net revenues accruing to the firm
- Taxes and royalties accruing to government
- Less cost of environmental damages - carbon tax

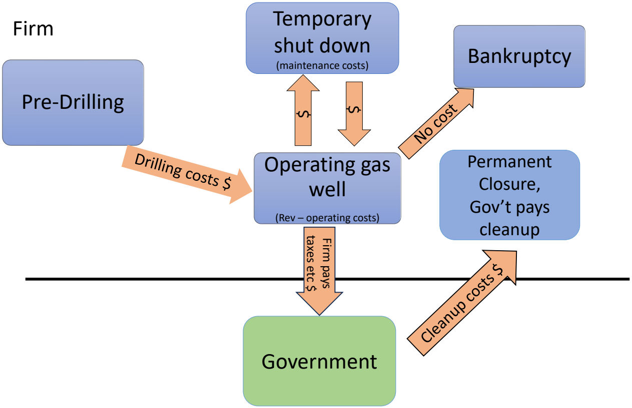
We consider **three regulatory approaches:**

- **Case 1:** An upfront **Cash Deposit** of 100% of cleanup costs
- **Case 2: No financial surety** required
- **Case 3:** An **annual surety payment** to a third party which guarantees the cleanup costs

Case 1: Cash flows with cash deposit, firm does not go bankrupt



Case 2: Cash flows with no surety, firm goes bankrupt



State variables

- Three state variables:
  - Natural gas price, P
  - Stock of remaining reserves, S
  - Stage of operation, δ

- **Natural gas price (P)** transformed to the risk-neutral measure:

$$dP(t) = \left(\eta(\bar{P} - P(t)) - \lambda\sigma\right)dt + \sigma P(t)dz; \; P(0) = p_0$$

dz is the increment of a Wiener process.
λ represents the market price of risk.

State variables

- **Stock of remaining reserves,** $S(t)$.

$$S(t) = S_0 - Q(t). \tag{1}$$

  where S_0 is the known stock of initial reserves, $Q(t)$ is cumulative production up to time t.

- $q(t)$ is rate of natural gas extraction and is determined by a known production decline curve.

- **The stage of operation;** $\delta_i, \quad i = 1, 2, 3$**:**
  - δ_1: pre-drilling
  - δ_2: active extraction
  - δ_3: temporary closure

Firm's controls

- "Feedback controls" dependent on the current price of natural gas, P, remaining reserves S, stage of operation, δ, and time, t
- Impulse controls defined at fixed (annual) decision times up to the lease end date, T.
- Controls are:
  - choice of operation stage, $\delta^+(P, S, \delta, t_m)$
  - the time to declare bankruptcy, $T_b(P, S, \delta, t_m)$ or the time to close the well and cleanup, $T_a(P, S, \delta, t_m)$.
- $\hat{T} = \min(T_a, T_b, T)$.

Bankruptcy

Assume the firm is bankrupt if the value of the well is negative.

- Affected by natural gas markets - price of natural gas
- Affected by firm's operating decisions - when to produce or shut in the well

Surety bond details

- For the surety bond case, the firm makes a known annual payment, X, to a guarantor.
- The guarantor agrees to pay cleanup costs, ζ_A, in the event of firm bankruptcy.
- The guarantor will only agree to this contract if *in the risk neutral measure*:

$$\mathbb{E}\left[\int_{t^s}^{\hat{T}} e^{-rt} X dt\right] = \zeta_A.$$

- For the numerical example, we consider $X =$ \$20k, \$75k, and \$100k per year.

Firm's cash flows from production and the surety

$$\pi(P(t),\delta(t),Q(t)) = \overbrace{\Big((1-\psi_R(P,q))P(t)-C_v\Big)q(t)-C_f}^{\text{cash flows from operations}}$$

$$+ \overbrace{r\Omega - X(t)}^{\text{financial assurance cash flows}} - \overbrace{\max\Big\{\psi_I\Big(\text{taxable income}\Big),0\Big\}}^{\text{income tax}} - \overbrace{\psi_C * q(t)}^{\text{carbon tax}}$$

- $\psi_R(P,q)$: royalty rate; ψ_I: corporate tax rate; ψ_C: carbon tax rate
- C_v: per unit variable costs; C_f fixed costs.
- $P(t)$: natural gas price; $q(t)$ natural gas extraction rate
- Ω: cash deposit; $X(t)$: surety payment rate

Firm's cash flows at termination, $\hat{T} = \min(T_a, T_b, T)$

Firm **Not Bankrupt:**

π_{T_a} = [Deposit refund - cleanup costs] = 0, *Cash deposit*

= - cleanup costs, *Surety bond*

Firm **Bankrupt:**

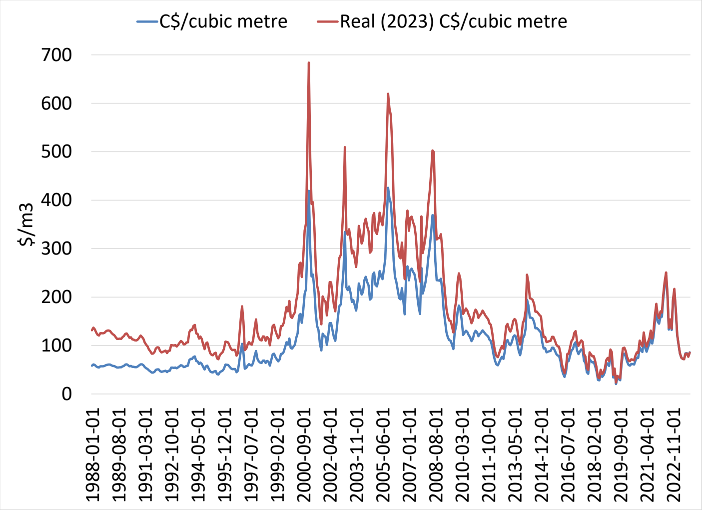
$\pi_{T_b} = 0$

- **No Surety or an Annual Surety Bond:** Firm chooses bankruptcy
- **100% cash deposit:** Firm cleans up, does not go bankrupt.

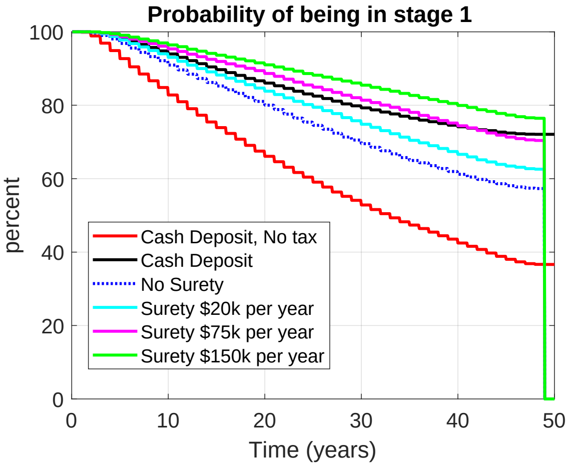
Numerical example for a hypothetical gas well

- Estimate parameters of the price process using data on Alberta "average field prices". Use a simple CAPM approach to estimate a market price of risk.
- Make assumptions re production costs, production decline curve and other needed parameters.

Alberta natural gas reference price

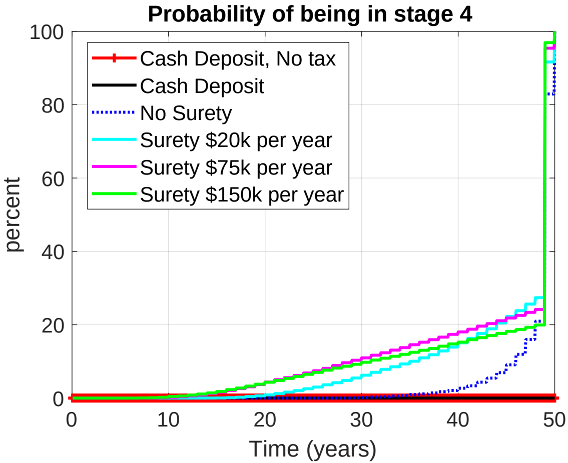


Probability of never drilling the well



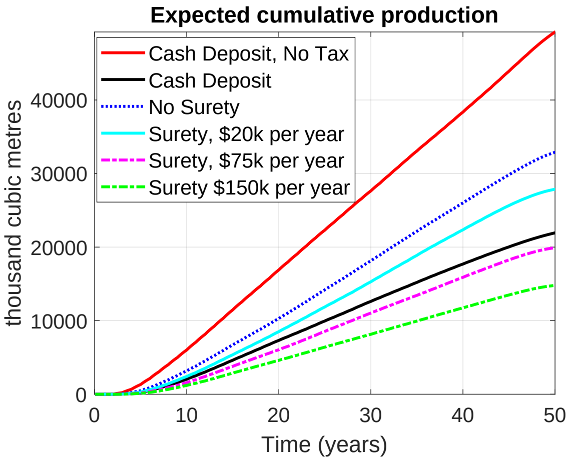
Given taxes, more likely to launch project with no surety. Least likely to launch with "fair" annual surety.

Probability of closing the well or going bankrupt

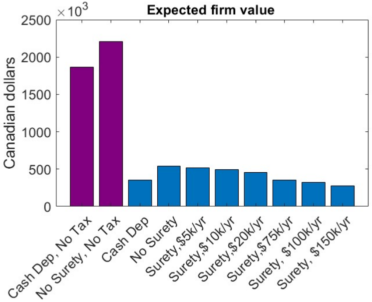


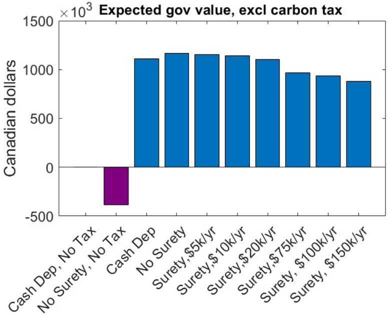
Given taxes, more likely to terminate prior to lease end date with "fair" annual surety.

Cumulative production

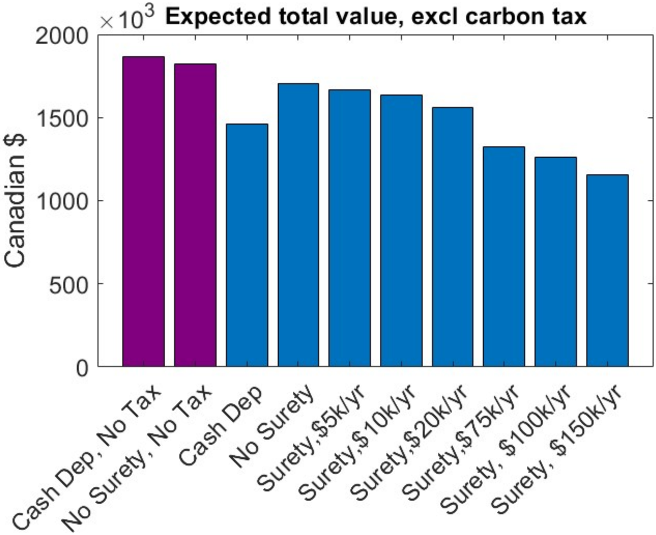


Given taxes, produce the most with no surety - more likely to open the well. Produce the least with high annual surety.

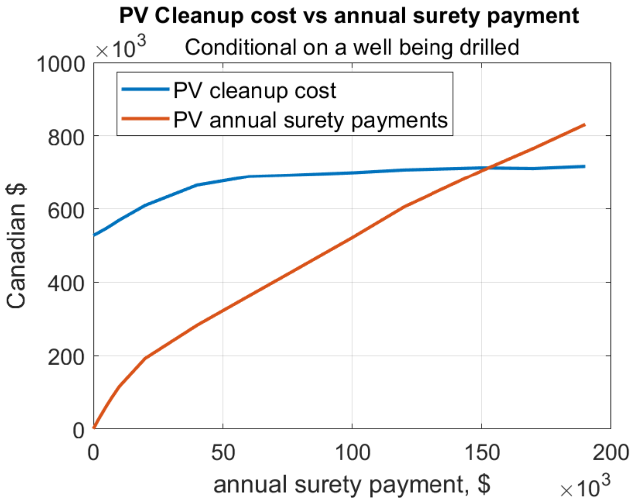




When taxes/royalties are present both government and firm expected values at time zero are highest with no surety.



Given taxes, total value is highest with no surety.



Expected PV of cleanup costs and PV total surety payments rise with the annual surety amount because firm declares bankruptcy sooner

Key results summary

- The ability to declare bankruptcy, and thereby avoid cleanup costs, is valuable to the firm.
    - Affects the firm's operating behaviour - with no financial surety, the firm produces more gas compared to with a 100 % cash bond.
- The value of the well to society is maximized when there are **no taxes** and a **100% cash bond** is imposed.
    - Firm acts optimally from the society's point of view.

Key results summary

- Oil and gas wells typically pay significant taxes and royalties, which changes our conclusions on the optimal policy.
  - With taxes, the total value of the project to society is largest when there is no surety required.
- **Given significant taxes and royalties: better off with no financial surety**:
  - Projects will be launched sooner and/or more projects will be undertaken.
  - More of the resource is produced.
  - Gov't is left to fund the cleanup, but this is offset by taxes and royalties paid to the government.

Key results summary

- An annual surety can be charged that will just cover the expected value of cleanup cost.
- But the total value of the project is less than when there is no surety.

The desirability of financial surety depends on ...

- The other revenues (taxes/royalties) received by the government from the firm.
- Also depends on how a firm's behaviour is changed by any financial surety.
  - In our example, the firm produces significantly less gas, which is inefficient.
  - In a the case of a mine, the firm might reduce waste production, which improves efficiency. (A result from a previous paper.)
- The issue must be looked at on an industry specific basis.

Caveats

- There is some evidence cleanup costs rise with time. We ignore this.
- Need a better estimate of environmental damages, and how these change over time.
- If the firm cannot borrow at its opportunity cost of capital, then the cost of an upfront bond will be higher than indicated in this analysis.