Finders, keepers?

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QUESTION AND MOTIVATION

Resource taxation is a large, even main, source of government revenue in many countries.

Quest for obtaining resource profits is often single most important public policy topic.

Can shift political sentiments, determine election outcomes, and even cause coups and wars.
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Goal: Explain a commonly observed feature of resource markets: cyclicality in resource taxation
Tax cycles in Bolivia

Sources: Jemio, 2008; WoodMackenzie, 2012
INVESTMENT CYCLES IN BOLIVIA

Source: UNCTAD
Other examples of cycles abound

- **Venezuela**: oil & gas, two cycles, 1935-today
- **Israel**: gas, one cycle, 2000-today
- **Argentina**: oil, three cycles, 1922-today
- **Zambia**: copper, two cycles, 1928-today
- **Peru**: oil & mining, two cycles, 20th century
- **Algeria**: oil & gas, two cycles, 1980s-today
- **Chile**: copper, two cycles, 1960s-today
- **Ecuador**: oil, one cycle, 1990s-today
- **Mongolia**: copper, one cycle, 1990s-today
- Many other countries and sectors (e.g. tin, coffee, agriculture, land development)
LITERATURE REVIEW

▶ The “natural resources trap”
  ▶ Hogan and Sturzenegger, 2010; Aghion & Quesada, 2010; Boadway & Keen, 2010; Engel & Fischer, 2010; Chang et al., forthcoming

▶ Dynamic commitment models
  ▶ Thomas & Worrall, 1994; Engel & Fischer, 2010

▶ Empirical perspectives on resource taxation
  ▶ Bohn & Deacon, 2000; Stroebel & van Benthem, 2013

▶ Tax and investment cycles
  ▶ Hassler et al., 2008; Manzano & Monaldi, 2008; Hajzler, 2012
CONTRIBUTION

- Rational-expectations model of resource taxation under limited ability of governments to commit to resource tax rates and firms to commit to exiting
  - Previous literature: exogenous expropriations, two-period models, or autarky punishments
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- Model endogenously generates repeated tax and investment cycles observed in practice
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- Rational-expectations model of resource taxation under limited ability of governments to commit to resource tax rates and firms to commit to exiting
  - Previous literature: exogenous expropriations, two-period models, or autarky punishments

- Model endogenously generates repeated tax and investment cycles observed in practice

- “Workhorse model” for a variety of extensions
**OUTLINE**

1. **Model of time-consistent resource taxation**
2. Basic results
3. Comparative statics
   - Delayed extraction profile
   - Price shocks
4. Extensions and conclusions
KEY ASSUMPTIONS

- Governments cannot commit to tax rates for more than a few years
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- Firms cannot commit to exiting a country for good
  - Describes Exxon, ConocoPhillips and other oil majors in Latin America
**Key Assumptions**

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- Firms cannot commit to exiting a country for good
  - Describes Exxon, ConocoPhillips and other oil majors in Latin America
- Mine lifetime exceeds the government’s period of commitment
  - Exploration and production lasts decades
  - Mines of different vintages exist simultaneously
KEY ASSUMPTIONS

- Governments cannot commit to tax rates for more than a few years
- Firms cannot commit to exiting a country for good
  - Describes Exxon, ConocoPhillips and other oil majors in Latin America
- Mine lifetime exceeds the government’s period of commitment
  - Exploration and production lasts decades
  - Mines of different vintages exist simultaneously
- Taxes not conditional on mine vintage
  - Most countries use fairly undifferentiated fiscal regimes
OUR SETUP

- Firms foresee possibility of reneging by future governments
OUR SETUP

▶ Firms foresee possibility of reneging by future governments

▶ Government in each point in time foresees this too
Our setup

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- Government may care about only current tax revenue, or the discounted sum of all future tax revenues
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- Government in each point in time foresees this too
- Government may care about only current tax revenue, or the discounted sum of all future tax revenues
TIMING

\[ t \quad t + 1 \]
Timing

\[ p_t \quad p_{t+1} \]

\[ t \quad t+1 \]
TIMING

Mines from $t - 1$: $e_{t-1}$

$p_t$  $p_{t+1}$

$t$  $t + 1$
TIMING

Mines from $t - 1$: $e_{t-1}$

$t$

$t + 1$
TIMING

Exploration: $e_t$

Mines from $t - 1$: $e_{t-1}$

$\tau_t$

$p_t$

$p_{t+1}$

$t$

$t + 1$
TIMING

Exploration: $e_t$

Mines from $t - 1$: $e_{t-1}$

Discounted with factor $\beta$

$p_t$

$p_{t+1}$

$t$

$t + 1$
TIMING

Exploration: $e_t$

Mines from $t - 1$: $e_{t-1}$

$\pi_t$

Discounted with factor $\beta$

$1 - \delta$

$t$

$t + 1$
TIMING

Exploration: $e_t \quad \delta \quad 1 - \delta$

Mines from $t - 1$: $e_{t-1}

\tau_t \quad \tau_{t+1}

Discounted with factor $\beta$

$P_t \quad P_{t+1}$

$t \quad t + 1$
TIMING

Exploration: $e_t$  \[\delta\]  1 - $\delta$  Discounted with factor $\beta$

Mines from $t - 1$: $e_{t-1}$

$\tau_t$  \[p_t\]  $\tau_{t+1}$  \[p_{t+1}\]

$t$  $t + 1$
SOLVING THE MODEL

Representative firm’s problem: Firm chooses exploration effort $e_t^* = E(\tau_t, \tilde{\tau}_{t+1})$, which depends on today’s and future tax rates.

Government’s problem: Government chooses tax policy $\tau_t^* \equiv T(e_{t-1}, \tilde{\tau}_{t+1})$.

Rational expectations: $\tilde{\tau}_{t+1} = \tau_{t+1}^*$ links “short-termist” governments through firm behavior!

Proposition: Cyclical pattern of taxes and exploration, but convergence to $\tau_{ss}$.
SOLVING THE MODEL
SOLVING THE MODEL

\[ \tau_t^* \]

\[ e_t \]
SOLVING THE MODEL

\[ \tau_t^* \]

\[ e_t \]

\[ t \]
SOLVING THE MODEL
SOLVING THE MODEL

\[ \tau_t^* \]

\[ e_t \]
SOLVING THE MODEL

\[ \tau_t^* \]

\[ e_t \]
SOLVING THE MODEL

\[ \tau_t^* \]

\[ 1 \]

\[ e_t \]
SOLVING THE MODEL
OUTLINE

1. Model of time-consistent resource taxation
2. Basic results
3. Comparative statics
   ▶ Delayed extraction profile
   ▶ Price shocks
4. Extensions and conclusions
SOLVING THE MODEL – BASE CASE

**Base case:** Suppose constant resource price \( (p_t = p \ \forall t) \) and a flat extraction profile \((\delta = \frac{1}{2})\). Then:

\[
\tau_{t+1} = \begin{cases} 
\frac{2}{p(2-\beta)}e_t + \frac{1+\beta}{2+\beta} & \text{if } e_t < \frac{p}{2} \frac{2-\beta}{2+\beta} \\
1 & \text{otherwise}
\end{cases}
\]

\[
e_t^* = \frac{p}{2} (2 - \beta) \left( \frac{1+\beta}{2+\beta} - \frac{1}{2} \tau_t \right)
\]
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\[
e_t^* = \frac{p}{2} (2 - \beta) \left( \frac{1+\beta}{2+\beta} - \frac{1}{2} \tau_t \right)
\]

Combining these, the tax transition and steady states become:

\[
\tau_{t+1} = \frac{2 + 2\beta}{2 + \beta} - \frac{1}{2} \tau_t
\]

\[
\tau_{ss} = \frac{2}{3} \frac{2 + 2\beta}{2 + \beta} \in \left( \frac{2}{3}, \frac{8}{9} \right)
\]
Implications for tax rates, production and investment

- **Prediction 1**: The tax in period \( t \) is negatively related to the tax in period \( t + 1 \)
Implications for tax rates, production and investment

- **Prediction 1:** The tax in period $t$ is negatively related to the tax in period $t + 1$
- **Prediction 2:** Within a time period there is a positive relationship between the tax rate and the value/productivity of the pre-existing mines
Implications for tax rates, production and investment

- **Prediction 1**: The tax in period $t$ is negatively related to the tax in period $t + 1$
- **Prediction 2**: Within a time period there is a positive relationship between the tax rate and the value/productivity of the pre-existing mines
- **Prediction 3**: Within a time period there is a negative relationship between the tax rate and mining investments (i.e., exploration and setting up of mines)
**IMPLICATIONS FOR TAX RATES, PRODUCTION AND INVESTMENT**

- **Prediction 1:** The tax in period $t$ is negatively related to the tax in period $t + 1$

- **Prediction 2:** Within a time period there is a positive relationship between the tax rate and the value/productivity of the pre-existing mines.

- **Prediction 3:** Within a time period there is a negative relationship between the tax rate and mining investments (i.e., exploration and setting up of mines).

- **Prediction 4:** The number of existing mines in period $t$ is negatively related to the number of existing mines in period $t + 1$. 
IMPlications FOR tax rates, production AND investment

➤ Prediction 1: The tax in period $t$ is negatively related to the tax in period $t + 1$

➤ Prediction 2: Within a time period there is a positive relationship between the tax rate and the value/productivity of the pre-existing mines

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➤ Prediction 4: The number of existing mines in period $t$ is negatively related to the number of existing mines in period $t + 1$
Tax cycles in Bolivia

Sources: Jemio, 2008; WoodMackenzie, 2012; Klein & Peres-Cajías, 2014; IEA, 2015
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**Delayed Extraction Profile**

- **Exploration:** $e_t$
- **Mines from $t-1$:** $e_{t-1}$
- **Periods:**
  - $t$
  - $t+1$

- **Probability Distribution:**
  - $\delta$
  - $1 - \delta$
Implications for the effect of delayed extraction

- **Prediction 5**: The more backloaded the mining profile is, the higher is the tax.
Implications for the effect of delayed extraction

- **Prediction 5**: The more backloaded the mining profile is, the higher is the tax

- **Prediction 6**: The more backloaded the mining profile is, the lower is exploration effort
Implications for the Effect of Delayed Extraction

- **Prediction 5:** The more backloaded the mining profile is, the higher is the tax.

- **Prediction 6:** The more backloaded the mining profile is, the lower is exploration effort.

- **Prediction 7:** The more backloaded the mining profile, the more pronounced are the tax cycles.
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Implications for the Effect of Price Shocks

- **Prediction 8**: Temporary price spikes raise the current tax and kick-start new cycles.
IMPLICATIONS FOR THE EFFECT OF PRICE SHOCKS

▶ **Prediction 8:** Temporary price spikes raise the current tax and kick-start new cycles

▶ Consistent with empirical evidence on expropriations (Guriev et al., 2011; Stroebel and van Benthem, 2013)
  ▶ 1 s.d. oil price increase → annual probability of expropriation increase by 0.84 percentage points
IMPLICATIONS FOR THE EFFECT OF PRICE SHOCKS

- **Prediction 8**: Temporary price spikes raise the current tax and kick-start new cycles

- Consistent with empirical evidence on expropriations (Guriev et al., 2011; Stroebel and van Benthem, 2013)
  - 1 s.d. oil price increase $\rightarrow$ annual probability of expropriation increase by 0.84 percentage points

- But, both in our model and in practice, prices are not the only driver of tax hikes...
**Tax cycles in Bolivia**

Sources: Jemio, 2008; WoodMackenzie, 2012; BP, 2015
Tax cycles in Venezuela

Sources: Monaldi, 2001; Manzano & Monaldi, 2008; WoodMackenzie, 2012; BP, 2015
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Model extended easily

- Price shocks
- Discovery shocks
- Government patience
- Endogenous commitment strategies
- Tax differentiation

These extensions show that the model is tractable and flexible, and that cycles are not inevitable.
CONCLUSIONS

▶ Time-consistent model with limited commitment can endogenously explain empirically prevalent repeated tax and investment cycles

▶ Tractable model offers a natural starting point for a variety of interesting extensions and empirical tests

▶ Model applies to capital taxation when capital is immobile (e.g., infrastructure, manufacturing)
Tax cycles in Venezuela

Sources: Monaldi, 2001; Manzano & Monaldi, 2008; WoodMackenzie, 2012
**Representative Firm’s Problem**

\[
\max_{e_t} \left[ (1 - \tau_t) \delta p_t + \beta (1 - \tilde{\tau}_{t+1})(1 - \delta)p_{t+1} \right] e_t - \omega_t e_t
\]

- \(e_t\): exploration effort
- \(\delta\): share extracted in period of exploration
- \(p_t, p_{t+1}\): prices
- \(\tau_t, \tilde{\tau}_{t+1}\): tax rates
- \(\beta\): discount factor
- \(\omega_t\): factor cost

Linear factor supply \((\omega_t = \bar{e}_t)\) and zero profit equilibrium condition yields \(e^*_t = E(\tau_t, \tilde{\tau}_{t+1})\)
**Government’s Problem**

\[
\max_{\tau_t} \left[ (1 - \delta)p_t e_{t-1} + \delta p_t e^*(\tau_t, \tilde{\tau}_{t+1}) \right]
\]

The optimal tax policy is \( \tau_t^* \equiv T(e_{t-1}, \tilde{\tau}_{t+1}) \)

Rational expectations: \( \tilde{\tau}_{t+1} = \tau_{t+1}^* \)
GOVERNMENT’S PROBLEM

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The optimal tax policy is \( \tau^*_t \equiv T(e_{t-1}, \tilde{\tau}_{t+1}) \)

Rational expectations: \( \tilde{\tau}_{t+1} = \tau^*_{t+1} \)

**Note.** The optimal tax is then

\[
\tau^*_t = T(e_{t-1}, \tau^*_{t+1})
\]
\[
= T(e_{t-1}, T(e^*, \tau^*_{t+2}))
\]
\[
= T(e_{t-1}, T(e^*, T(e^*_{t+1}, \tau^*_{t+3})))
\]
\[
= \ldots
\]

“Short-termist” governments linked by firm behavior!
MARKOV-PERFECT EQUILIBRIUM

Guess and verify that the solution to each government’s problem is a piecewise linear function of the stock of old mines; and to each firm’s problem a piecewise linear function of the current tax

\[
\tau_t = A_t e_{t-1} + B_t, \quad e_t = C_t \tau_t + D_t
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Markov-perfect equilibrium

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\[ \tau_t = A_t e_{t-1} + B_t, \quad e_t = C_t \tau_t + D_t \]
Suppose prices are constant but $\delta \in (0, 1)$

$$
\tau_{t+1} = \frac{1}{\delta} \frac{1 + \beta^{1-\delta}}{2 + \beta^{1-\delta}} - \frac{1}{\delta} \frac{1 - \delta}{2} \tau_t
$$

$$
\tau_{ss} = \frac{1}{1 + \delta} \frac{2 + 2\beta^{1-\delta}}{2 + \beta^{1-\delta}}
$$

Policy rules converge for large enough $\delta$
EXTENSION: RESOURCE DISCOVERY SHOCKS

Sources: Jemio, 2008; WoodMackenzie, 2012

Discovery shocks change tax rates and initiate cycles

Back to model extensions
PATIENT GOVERNMENTS AND COMMITMENT

Are cycles inevitable?

**Patient governments**: tax and exploration cycles persist even if governments value future tax revenues

---

Endogenous commitment: trigger strategies to support moderate tax rates:

- **Commitment**: set Laffer taxes $\tau = \frac{1}{2}$ if firms explore as under Laffer tax earlier

- **Punishment**: follow defections by reverting to Markov

Proposition: Subgame perfect equilibrium if and only if government is sufficiently patient and the initial reserves are sufficiently small
**Patient Governments and Commitment**

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**Proposition:** Subgame perfect equilibrium if and only if government is sufficiently patient and the initial reserves are sufficiently small
TAX DIFFERENTIATION

Would it make things better or worse if the government can set separate taxes on old and new mines?

Result 1: Exploration is higher under tax differentiation

Result 2: Total tax revenues are higher under tax differentiation

Independent of how patient firm is

Back to model extensions
**Tax Differentiation**

- Would it make things better or worse if the government can set separate taxes on old and new mines?

- Use impatient-government setup

- Under tax differentiation, the government would always expropriate old mines ($\tau_{t,old} = 1$). Bad!

- But it can focus tax on new mines to incentivize new investment ($\tau_{t,new} = 1/2$). Good!
TAX DIFFERENTIATION

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▶ Result 1: Exploration is higher under tax differentiation
▶ Result 2: Total tax revenues are higher under tax differentiation
▶ Independent of how patient firm is