A Dynamic Theory of Resource Wars

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Control of natural resources key determinant of war. 14 out of 20 major wars between 1878 and 1918 (Bakeless 1921)
Motivation

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- Klare argues that after the Cold War, resources will become a primary motivation for wars in the future.
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Klare argues that after the Cold War, resources will become a primary motivation for wars in the future.

Carter doctrine: "Any attempt by any outside force to gain control of the Persian Gulf ... will be repelled by any means necessary, including military force"
Main questions

- What is the effect of resource scarcity on the likelihood of war?
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- How does the threat of war affect resource extraction and prices?
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- How does the threat of war affect resource extraction and prices?

- How are these wars affected by the price structure?
Develop a dynamic model of resource wars.
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Elasticity of demand is a key parameter to determine the incentives of war.
Results

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- Firms fail to internalize the impact of their extraction on military action, under inelastic demand → war incentives increase over time and war may become inevitable.
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In some situations regulations in the resource rich country can prevent war.
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- Firms fail to internalize the impact of their extraction on military action, under inelastic demand → war incentives increase over time and war may become inevitable.

- In some situations regulations in the resource rich country can prevent war.

- Limited commitment implies that regulation might precipitate war even in situations where war would not have arisen under competitive markets.
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- Two goods, resource and consumption good. Two countries, $A$ and $S$ (resource rich country)

- Government maximize inter temporal utility of citizens (mass 1 of identical households or representative household)

- In each period both countries are endowed with exogenous perishable amount of the consumption good, normalized to zero. $S$ has $e_0$ units of resource in $t = 0$. 
Instant utility of $S$

\[ c^S_t \] (1)
Country $S$

- Instant utility of $S$

\[
    c^S_t
\]  

- $x_t$ (Amount extracted) is non storable, and $e_t$ (reserve of resources) follows the law of motion

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e_{t+1} = e_t - x_t
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Trade occurs with country $A$ in different environments.
Country $A$

Instant utility of $A$

$$u(x^A_t) + c^A_t$$

(3)

$x^A_t \geq 0$ is consumption of the resource, $c^A_t \in \mathbb{R}$ of the consumption good and $u(.)$ with the usual properties.
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$x_t^A \geq 0$ is consumption of the resource, $c_t^A \in \mathbb{R}$ of the consumption good and $u(\cdot)$ with the usual properties.

- Can also make two additional decisions, how much to arm $m_t \in [0, \bar{m}]$ and whether to declare war to $S$. We say that $f_t = 1$ if war has occurred before $T = t$. 
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- Cost of $m_t$ is $l(m_t)$ with $l'(.) > 0, l''(.) \geq 0, l(0) = 0$
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- Can also make two additional decisions, how much to arm \( m_t \in [0, \bar{m}] \) and whether to declare war to S. We say that \( f_t = 1 \) if war has occurred before \( T = t \).

- Cost of \( m_t \) is \( l(m_t) \) with \( l'(\cdot) > 0, l''(\cdot) \geq 0, l(0) = 0 \)

- Payoff from war \( w(m_t)e_t \). Where \( w_t(\cdot) \in [0, 1] \). In case of war, A gets \( w(m_t) \) and the rest is destroyed. \( w(0) = 0, w'(m) \xrightarrow{m \to \bar{m}} 0 \)
Payoff for $A$ if it goes to war $V(w(m_t)e_t) - l(m_t)$ were:

\[ V(w(m_t)e_t) = \max_{\{x_{t+k}, e_{t+k+1}\}} \sum_{k=0}^{\infty} \beta^k u(x_{t+k}) \]  

(4)

\[ e_{t+k+1} = e_{t+k} - x_{t+k} \]  

(5)

\[ e_1 = w(m_t)e_t - x_t \]  

(6)

\[ x_{t+k}, e_{t+k} \geq 0, \text{ for } k \geq 0 \]  

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Define $m(e_t)$ as the arg max of the payoff if $A$ goes to war, then
Proposition

If \(-u'(x)/(xu''(x)) < 1\), then \(m^*(e) < 0\). Conversely, if \(-u'(x)/(xu''(x)) > 1\), then \(m^*(e) > 0\)
Unit measure of firms in country S. Each labeled $i$ and with equal initial endowment. Extraction $x_{it}^S$ sold at price $p_t$. 
Unit measure of firms in country S. Each labeled $i$ and with equal initial endowment. Extraction $x_{it}^S$ sold at price $p_t$

Each firm’s problem is

$$\max_{\{x_{ti}\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t p_t x_{ti}^S$$

subject to

$$e_{it+1} = e_{it} - x_{it}^S \text{ if } f_t = 0$$
$$x_{ti}^S = 0 \text{ if } f_t = 1$$
$$x_{ti}^S, e_{it} \geq 0 \forall t \geq 0$$
Then, when $f_t = 0$, we have:

$$x_{ti}^S \begin{cases} 
= 0 & \text{if } p_t < \beta p_{t+1} \mathbb{P}\{f_{t+1} = 0\} \\
\in [0, \min\{\bar{x}, e_{it}\}] & \text{if } p_t = \beta p_{t+1} \mathbb{P}\{f_{t+1} = 0\} \\
= \min\{\bar{x}, e_{it}\} & \text{if } p_t > \beta p_{t+1} \mathbb{P}\{f_{t+1} = 0\}
\end{cases}$$

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Then, when $f_t = 0$, we have:

$$x^S_{ti} = \begin{cases} 
0 & \text{if } p_t < \beta p_{t+1} \mathbb{P}\{f_{t+1} = 0\} \\
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\end{cases} \quad (9)$$

**Country A** will demand a solution to

$$\max_{x_t^A} u(x_t^A) - p_t x_t^A \quad (10)$$

Which gives us

$$u'(x_t^A) = p_t \quad (11)$$
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- Finally, market clearing implies

\[
x^S_t - x^A_t
\]  

(12)
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4. Extraction and consumption takes place.
We want to find a Markov Perfect Competitive Equilibrium.
Equilibrium

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Strategy $\varphi$ of $A$, is a pair of functions, $\varphi^m$ is a distribution over the possibles $m$ given $e_t$. $\varphi^f$ assign a probability of attacking as a function of $(e_t, m_t, p_t, x_t^S, x_t^A)$. 

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Call \( \gamma = \{e_t^*, m_t^*, p_t^*, x_t^{S*}, x_t^{A*}\}_{t=0}^{\infty} \) the values which would arise in case \( f_{t-1} = 0 \).
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Given $\gamma$, let $U_A(e)$ the payoff for country $A$ starting with $e$. Then the period $t$ payoff conditional on some choice $(m_t, f_t)$ is

$$
(1 - f_t)(u(x_t^A) - \beta U_A(e_t^{*+1}) + f_t V(w(m_t)e_t^*) - l(m_t))
$$

(13)
Definition

A MPCE consist of $\varphi$, $\gamma$ such that at each $t$:

1. $\varphi^m$ maximizes 13 for each $e_t^* > 0$ in $\gamma$
2. $\varphi^f$ maximizes 13 given $m_t$ for every $(e_t^*, m_t^*, p_t^*, x_t^{S*}, x_t^{A*})$ with $e_t^* > 0$ in $\gamma$
3. $\gamma$ satisfies 2, 9, 11, 12 with $P\{f_{t+1} = 1\} = \varphi^f(\ldots)$
4. If $e_t^* = 0$, then $\varphi_v(e) = \lim_{e \to 0} \varphi_v(e)$ where $\varphi_v(e)$ is the strategy that for country $A$ that maximizes 13 for some cost of war $v > 0$. 

First three condition are standard. Fourth condition is a refinement to avoid multiple equilibria.
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Lemma (2)

An MPCE exists.
No Capacity Constraints ($\bar{x} = +\infty$)

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Proposition (2)

In any pure-strategy MPCE

- War can only occur at $t = 0$ along the equilibrium path.
- The equilibrium sequence of resources extraction satisfy
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\[
\beta u'(x_{t+1}) = u'(x_t) \tag{14}
\]

- In case \( A \) attacks in \( T \), \( S \) takes all the resources before.
A Dynamic Theory of Resource Wars

No Capacity Constraints ($\bar{x} = +\infty$)

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- Fourth condition of MPCE allows $A$ to attack only if $u(0) = -\infty$
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- In case $A$ attacks in $T$, $S$ takes all the resources before.
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  \[ u(0) = -\infty \]
- Then it is profitable to attack earlier.
Comments on Proposition 2

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- Imagine it is optimal for A to go to war at some point $T$, and consumer there are strictly better at $0$ under permanent peace that under immediate war. A could commit to not going to war in the future. This would make everyone happier.
- Second part, resource extraction is the same that under no war. (hotelling rule)
Reminder, CRRA or iso-elastic preferences are such that

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Reminder, CRRA or iso-elastic preferences are such that

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In this case, proposition 2 is generalized to any MPCE (also with mixed strategies), given $\sigma \neq 1$.

Depending on $\sigma$, war will occur if the initial endowment of resources is big enough ($\sigma > 1$), or if $A$ can get enough of $e$ in case of a war.
Proposition (4)

Suppose $u(x)$ is CRRA and $\sigma \neq 0$,

1. Suppose $\sigma > 1$, then there exist $\hat{\epsilon} > 0$ such that if $e_0 < \hat{\epsilon}$, then the unique MPCE has permanent peace, and if $e_0 > \hat{\epsilon}$ in any MPCE war occurs in period 0 with probability 1.

2. Suppose $\sigma < 1$, then there exist $\hat{w} < 1$ such that if $\lim_{m \to \tilde{m}} w(m) < \hat{w}$, then the unique MPCE has permanent peace, and if $\lim_{m \to \tilde{m}} w(m) > \hat{w}$ in any MPCE war occurs in period 0 with probability 1.
If demand is inelastic, then spending is increasing over time, if $A$ gets enough of the resources, then is optimal to go to war.
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This conclusion does not depend on the cost of war.
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Case \( \sigma = 1 \) has multiple eq. in particular, randomizing going to war in every period.
Back again to the general utility case, then

**Proposition (5)**

Suppose there exist some $\bar{\sigma} < 1$ such that $-u'(x)/(xu''(x)) \leq \bar{\sigma} \forall x > 0$, and suppose that $\lim_{m \to \bar{b}} w(m)$ is sufficiently close to 1. Then

1. An MPCE exists
2. In any MPCE, war occurs with probability 1 before some $T < \infty$, and $x_t = \bar{x}$ if war has not yet occurred.
3. If $\bar{x} \geq e_o$ then war occurs in period 0.
Intuition similar as before.
Comments on proposition 5

- Intuition similar as before.

- Demand inelastic $\implies$ spending increasing over time $\implies$ optimal to declare war at some point.
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- Demand inelastic $\Rightarrow$ spending increasing over time $\Rightarrow$ optimal to declare war at some point.

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However, firms extract faster than they would otherwise.

Mixed incentives for $A$, earlier war avoids rapid depletion of resources. Later war to postpone cost of armaments and resources. The time of war is not monotonic on $T$. 
Competitive eq. sub optimal for $S$: 

Firms don’t internalize (last case) that increase in price increases incentives to go to war. It might be beneficial to regulate prices and quantities. However, they show that even though this externalities go away, we have a new one due to the lack of commitment of $S$. Focus on price and quantity regulation, not in cases in which $S$ can only regulate one of those.
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Monopolistic Environment

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3. Country A’s government decides whether or not to accept the offer. If declines, it can declare war.
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2. Country $S$’s government makes a take-it-or-leave-it offer $z_t$ to country $A$. Exchange $x_t^0$ for $c_t^0$ units.

3. Country $A$’s government decides whether or not to accept the offer. If declines, it can declare war.

4. Extraction and consumption takes place.
Equilibrium

We want to find a Markov Perfect Competitive Equilibrium (In this case, Markov Perfect Monopolistic Equilibrium).
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Strategy for $A$ $\phi_A = \{\phi^m_A, \phi^a_A, \phi^f_A\}$ of $A$, where, $\phi^m_A$ is a distribution over the possibles $m$ given $e_t$. $\phi^a_A$ assign an acceptance decision as a function of $(e_t, m_t, x^o_t, c^o_t)$, $\phi^f_A$ assign a probability of attacking as a function of $(e_t, m_t, x^o_t, c^o_t, a_t)$, and it is zero if $a_t = 1$. 
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Strategy for \( A \) \( \phi_A = \{ \phi^m_A, \phi^a_A, \phi^f_A \} \) of \( A \), where, \( \phi^m_A \) is a distribution over the possibles \( m \) given \( e_t \). \( \phi^a_A \) assign an acceptance decision as a function of \( (e_t, m_t, x^o_t, c^o_t) \), \( \phi^f_A \) assign a probability of attacking as a function of \( (e_t, m_t, x^o_t, c^o_t, a_t) \), and it is zero if \( a_t = 1 \).

Strategy for \( S \), \( \phi_S = \{ \phi^x_A, \phi^c_A \} \) and \( \phi_S \) function of \( (e_t, m_t) \).
A MPME is a pair \( \{ \phi_S, \phi^m_A \} \) where:

1. Given \( \phi_S, \phi^m_A \) maximize welfare for \( A \) for any \( e_t, \phi^a_A \) maximize welfare for \( A \) for every \( (e_t, m_t, x^0_t, c^0_t) \), and \( \phi^f_A \) maximize welfare for \( A \) for every \( (e_t, m_t, x^0_t, c^0_t, a_t) \) conditional on \( f_t = 0 \) if \( a_t = 1 \).

2. Given \( \phi_A, \phi_S \) maximize welfare for \( S \) for any \( (e_t, m_t) \)
$S$ will have two kind of strategies, either leave $A$ indifferent between war or not, or just make $A$ going to war.
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**Proposition (6)**

In any MPME if $f_{t+1} = 0$ then

\[ \beta u'(x_{t+1}) > u'(x_t) \text{ if } m^*(e_{t+1}) > 0 \]  \hspace{1cm} (15)

\[ \beta u'(x_{t+1}) < u'(x_t) \text{ if } m^*(e_{t+1}) < 0 \]  \hspace{1cm} (16)
Corollary

In any MPME, whenever $f_{t+1} = 0$, we have that:

\[ -\frac{u'(x)}{xu''(x)} > (<)1 \text{ for all } x, \text{ then } \beta u'(x) > (<)u'(x) \]
Corollary

In any MPME, whenever $f_{t+1} = 0$, we have that:

$$\text{if } -\frac{u'(x)}{x u''(x)} > (<)1 \text{ for all } x, \text{ then } \beta u'(x) > (<)u'(x)$$

How the shadow prices evolve depends on the elasticity.
Corollary

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- How the shadow prices evolve depends on the elasticity.
- When demand is inelastic, value of the resource is increasing. Then Country $A$ invest more in arms. This makes $S$ to extract less to reduce incentives to arm.
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In any MPME, whenever \( f_{t+1} = 0 \), we have that:

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- How the shadow prices evolve depends on the elasticity.
- When demand is inelastic, value of the resource is increasing. Then Country A invest more in arms. This makes \( S \) to extract less to reduce incentives to arm.
- When demand is elastic, value of the resource is decreasing. Then Country A armaments are decreasing, this makes \( S \) to extract more to reduce incentives to arm.
Corollary

In any MPME, whenever $f_{t+1} = 0$, we have that:

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Proposition (7)

Suppose \( u(x) \) is CRRA, then in any MPME,

1. War is avoided when \( \sigma < 1 \) and
   \[
   -\beta l(\bar{m}) > \psi(1 - \beta)
   \]

2. War can be avoided when war necessarily occurs in an MPCE.

3. War can occur with probability 1 along the equilibrium path if \( \sigma < 1 \).

4. War can occur with probability 1 along the equilibrium path when war is necessarily avoided in the MPCE.
If war is too costly for country $S$, then it can be avoided.
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Second part is a consequence of the first one.
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3. The opposite of the previous results can also be true. This happens when the cost of war is not high for $S$. The key is that here $A$ has to invest even if there is no war. $S$ can not commit to make offers unless it has a threat of war. Then $S$ compensates $A$ for future cost of armament. If these costs are increasing, at some point $S$ could prefer going to war.
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4. Two opposite forces. First, $S$ controls the extraction, then the externalities of the competitive firms. Second, introduces another strategic interaction, because it can not commit to good terms if $A$ is not armed.
Proposition 6 holds, but now with $x_t, x_{t+1} < \bar{x}$. 

Corollary only changes because instead of having it for all $x_t$, the first one holds only after some $T < \infty$. Intuition is the same.
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Intuition is the same.
Case Studies

Two cases that illustrate the insights of this paper (role of scarcity, elasticity, price regulation)

1. War of the Pacific (Perú - Bolivia vs Chile)
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   - Increase of price related to increase in militar expenditure.
Case Studies

1. Cedar Wars (Kasoff, 1997)

In the Ancient Lebanon, between Egyptians, Mesopotamian, Phoenicians. Cedars of Ancient Lebanon were important and natural resource, and appear to have been a major factor in the Cedar Wars. Not only the value, but also potential future scarcity. During 734, and 733-732 BC, Assyrian King, who controlled Phoenicia, imposed a trade embargo to Egypt. Cedars were impossible to substitute, so Egypt supported rebellions against Assyrian. They interpret this as a way to change the terms of trade.
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Extensions

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3. Domestic political economy issues.
Conclusions

1. If the resource is extracted by price-taking firms, then fail to internalize their effect on future military action by the other country. If demand is inelastic, this accelerates war.
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2. Externalities can be internalize by the government. If demand is inelastic, it can slow down extraction so it slows down the rise in armaments. In the other case, can reduce armaments costs by extracting more.
Conclusions

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2. Externalities can be internalize by the government. If demand is inelastic, it can slow down extraction so it slows down the rise in armaments. In the other case, can reduce armaments costs by extracting more.

3. However, lack of commitment makes the resource rich country to pay the future costs of armaments to prevent war, making war more likely to occur.