Strategic Oil Dependence

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Reyer Gerlagh

University of Manchester
Institute for Environmental Studies, Vrije Universiteit Amsterdam

Matti Liski

Helsinki School of Economics

Thanks to: Michael Hoel & Centre for Advanced Studies, Norwegian Academy of Sciences and Letters, Oslo

Email: reyer.gerlagh@manchester.ac.uk
Web: personalpages.manchester.ac.uk/staff/Reyer.Gerlagh/

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The Question

- Sustainability
  - 1970s concern for exhaustible resources (oil crisis)
  - 2000s concern for climate change
  - 2030s what if they meet?

- Second look at exhaustible resources
  - Hotelling model as main economic tool of analysis, but this model does not say anything about the following:

- In the oil market sellers communicate like central bankers, emphasizing credibility and security of supply

- Why do sellers care about security of supply?

THE ANSWER

- “We've got almost 30 percent of the world's oil. For us, the objective is to assure that oil remains an economically competitive source of energy. Oil prices that are too high reduce demand growth for oil and encourage the development of alternative energy sources” (Adel al-Jubeir, foreign policy adviser of crown prince Abdullah (Saudi Arabia), Herald Tribune, Jan 24, 2007).

US-Saudi relationship

- Saudi Arabia and US have a close highly strategic relationship
- US shows buyers' trust: maintaining oil dependence
- Saudi Arabia promises secure supply: compensation for costly oil dependence

THE QUESTION, CTD

- Saudi Arabia has always kept oil prices low, and stressed reliability of their supply of affordable oil.

- Now prices increase.
  - Just a normal increase in Hotelling rent?
  - Current prices make ‘heavy oil’ + tar sands in Canada profitable. Don’t the oil suppliers worry for the development of substitutes anymore?

- When oil suppliers accept higher prices, what does this signify?

The Analysis

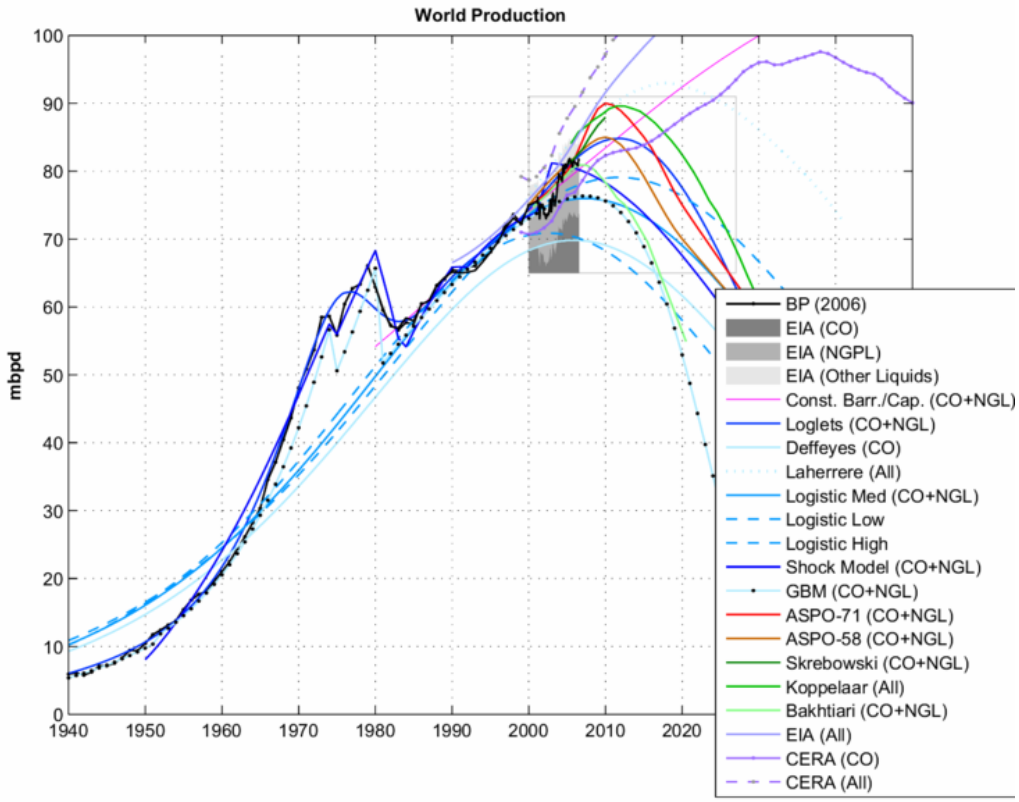
- Both sellers and buyers can act strategically.
  - The buyer can threaten to develop a substitute.
  - The seller can entice the buyer not to do so by supplying 'cheap oil'.
- The Hotelling model does not capture this interaction. What model would capture it, and what would the model suggest for the oil extraction path?

Energy & Climate

- Energy & Climate are tied together
  - Energy savings lower demand for oil and capture part of resource rent, but don't change long-term oil dependency.
  - Alternative Energy development also reduces oil demand but also threatens perceived future oil demand.
  - This interaction has not been analyzed before.

Peak Oil

- Initially supplies increase due to increasing demand + exploitation innovation. But as oil+gas is exhaustible, inevitably, supplies must come down at some point in time.
- In the middle, there is a maximum supply, the ‘peak’.



Peak Oil, ctd

- What is surprising is not the peak, but the uncertainty.
- Oil ownership is very concentrated, and the buyers don't know the true reserves (asymmetry in information)
  - We don't know whether we are on the peak, or that we have some more years to go.
  - For such an essential factor of production, that is quite amazing. It tells us something about the owners.
  - OPEC members self-report, but they are suspected to do so strategically.

- How will the future remember 2000-2050?
  - The beginning of a 'clean' energy era
  - The decline of global oil+gas supplies (peak oil)

Peak Oil + Climate

- To keep in mind
  - Oil + Gas (unproven) reserves are between 500 and 2000 $GtCO_2$. This may all be burnt if spread evenly, and still remain under 550 ppmv target.

- The question seems not whether we have to switch from oil to alternatives, but when we will switch and to what
  - Wind + solar + storage technology
  - Heavy oil + Coal (+ CCS)
  - Nuclear, or some unknown alternative

- How will the oil sellers use their strategic power and use their information on true oil reserves?
- How will buyers use their strategic power on developing substitutes?

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The Oil Buyer

- Buyer-side has an interest in ending the relationship:
  - macroeconomic risks (oil shocks are bad for the economy)
  - environmental externalities (oil is bad for air quality and climate)
  - finite supply of cheap oil & transition to substitutes is long. The longer one waits, the more expensive it might be to live on low supplies.

- Coordination problem: Climate change asks for coordination, will substitute development be part of that?
  - Stern review (2006) (a political document to prepare joint action)
  - Soft coordination. No need for one agent who invests in oil substitute. A coordinated price signal (carbon price, emission permit market) may suffice.

THE SELLER

- resource not managed like most productive assets
  - ownership of the cheap oil reserve is extremely concentrated
  - management of cheap oil is characterized by secrecy
  - potential risk associated with OPEC's role as the central banker of the oil market (cf. the ‘peak oil’ discussion)

The Equilibrium

- Allocation problem: how much should be saved for the transition?
  - What is social optimum
  - What is seller's optimum
  - What is buyer's optimum
- The buyer can decide sovereign on the development of a substitute
  - What is equilibrium: can sellers distort buyer-side effort to end the relationship?

LITERATURE

- Hotelling's theory of exhaustible-resource consumption (1931)
- Nordhaus' (1973) concept of a backstop technology

Strategic equilibria in resource economics

- optimal tariffs on exhaustible resources (Newbery, 1983, Maskin and Newbery, 1990; see Karp and Newbery 1993 for a review)
- Development of substitute technologies that have a permanent effect on the resource dependence (lasting and thus larger effect)
  - Stackelberg leadership (Dasgupta et al. 1983, Gallini et al. 1983, and Hoel 1983)
  - Commitment (Lewis et al., 1986)
  - Stochastic innovation (Harris and Vickers, 1995)

Our Paper

- Before going into climate change policy, multiple substitutes, multiple buyers, multiple sellers, we ask:
- One buyer, one seller, one substitute that needs costs and time to build, no commitment = time consistent policy

- What is the effect on exhaustible resource supply & prices?

- Then after we solve that, I look forward to your thoughts on the more complex context.
- During this presentation: ‘waving hands’ (paper is quite robust)

Our Model

Market structure

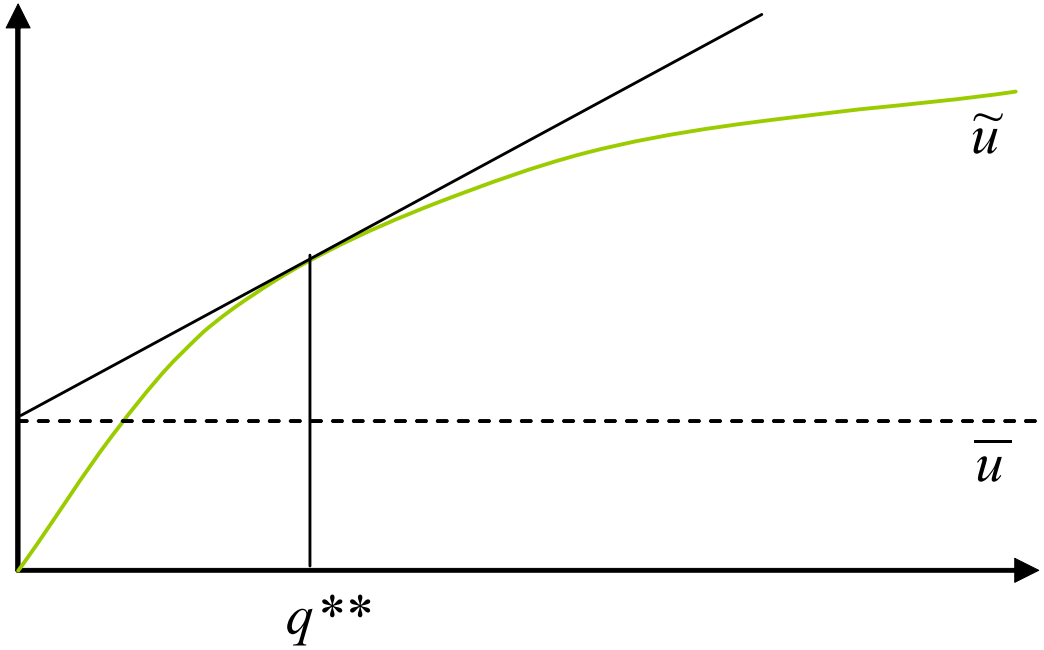
- Both sellers and buyers enjoy some power so that no party is in explicit leadership
- The nature of the strategic interaction between buyers and sellers is preserved in the limiting case without discounting
  - allows an essentially static analysis
  - and shows the way to analyze the discounted case
- We abstract from the precise instrument implementing the structural change in demand
  - When action is taken, it changes the demand irreversibly after a time lag.
  - This abstraction simplifies the strategic variable on the buyer side while keeping what seems essential in the relationship.

Model Building Blocks

- One resource (oil) with stock S_t, supply q_t : $S_t = \int_t^\infty q_\tau \, \mathrm{d}\tau$
- Buyer derives utility from consumption of resource: $\tilde{u}(q_t)$
- Price is marginal utility: $p_t = \tilde{u}'(q_t)$
- Consumer surplus: $u(q_t) = \tilde{u}(q_t) - p_t q_t = \tilde{u}(q_t) - \tilde{u}'(q_t) q_t$
- Profits (concave): $\pi(q_t) = p_t q_t = \tilde{u}'(q_t) q_t$
- Utility: $\tilde{u}(q_t) = u(q_t) + \pi(q_t)$
- Buyer can invest in development of substitute, at cost I, delivering a substitute after k periods that makes resource redundant and provides backstop surplus $\bar{u}$.
- Welfare is measured relative to long-term: $\tilde{u}(q_t) - \bar{u}$

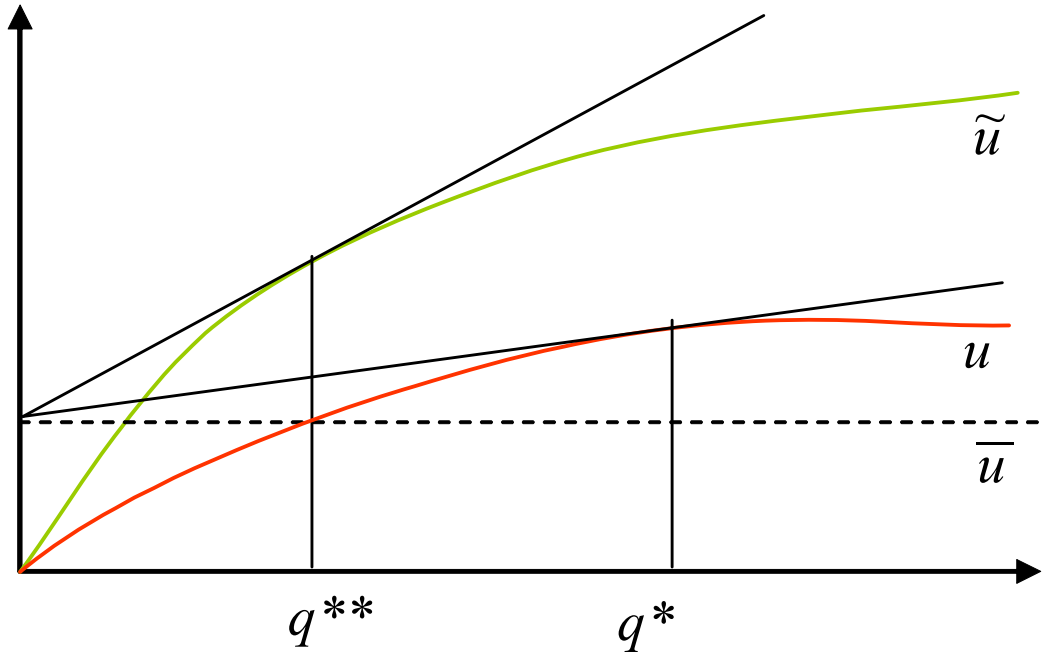
Social Optimum

- Max $\int_0^{T+k}[\tilde{u}(q_t)-\bar{u}]\,\mathrm{d}t$ s.t. $S_0=\int_0^{T+k} q_t\,\mathrm{d}t$
- Optimum maximizes average value of resource:
- $q_t{=}q^{**}$ = Max $[\tilde{u}(q_t)-\bar{u}]/q_t$
- $\tilde{u}(q^{**})=\bar{u}+q^{**}\tilde{u}'(q^{**})\Rightarrow u(q^{**})=\bar{u}$
- Buyer does not benefit from extra resource



BUYER'S OPTIMUM

- Max $\int_0^{T+k}[u(q_t)-\bar{u}]\,\mathrm{d}t$ s.t. $S_0=\int_0^{T+k} q_t\,\mathrm{d}t$
- Optimum maximizes average value of resource:
- $q_t{=}q^*$ = Max $[u(q_t)-\bar{u}]/q_t$
- $u(q^*)=\bar{u}+q^*u'(q^*)$
- Buyer benefits from extra resource



SELLER'S OPTIMUM

- Max $\int_0^{T+k} \pi(q_t)\,\mathrm{d}t$ s.t. $S_0 = \int_0^{T+k} q_t\,\mathrm{d}t$
- Maximum maximizes average value of resource = price(!):
- Seller wants to spread supply as thinly over time as possible to sell at maximal price $\max p = \tilde{u}'(0)$

- But buyer will not accept sale below q^{**}, with $u(q^{**}) = \overline{u}$, or invest immediately.
- Thus the question is, in equilibrium, where will supply lie between seller's interest of minimal supply and buyer's interest of higher supply: $q^{**} \leq q_t \leq q^*$

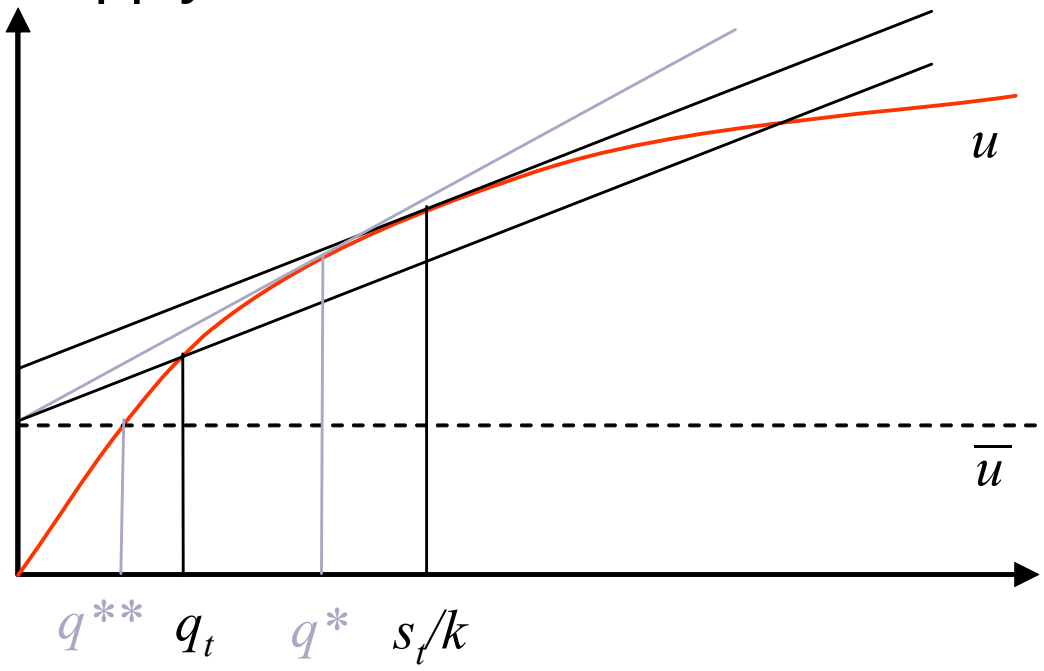
EQUILIBRIUM

- In paper, we prove Markov equilibrium satisfies simple arbitrage condition.

- Buyer can choose between investing now, investing tomorrow, or investing later.
- Opportunity value of resource is aggregate consumer surplus when investing now: $W(s_t) = k[u(s_t / k) - \bar{u}]$
- Indifference condition: not investing now = accepting supply q_t for ε period of time, should leave the buyer with the same welfare
  - Utility excess compared to substitute: $u(q_t) - \bar{u}$
  - Decrease in surplus during transition: $-q_t W'(s_t)$
  - $u(q_t) - \bar{u} - q_t W'(s_t) = 0 \Rightarrow$

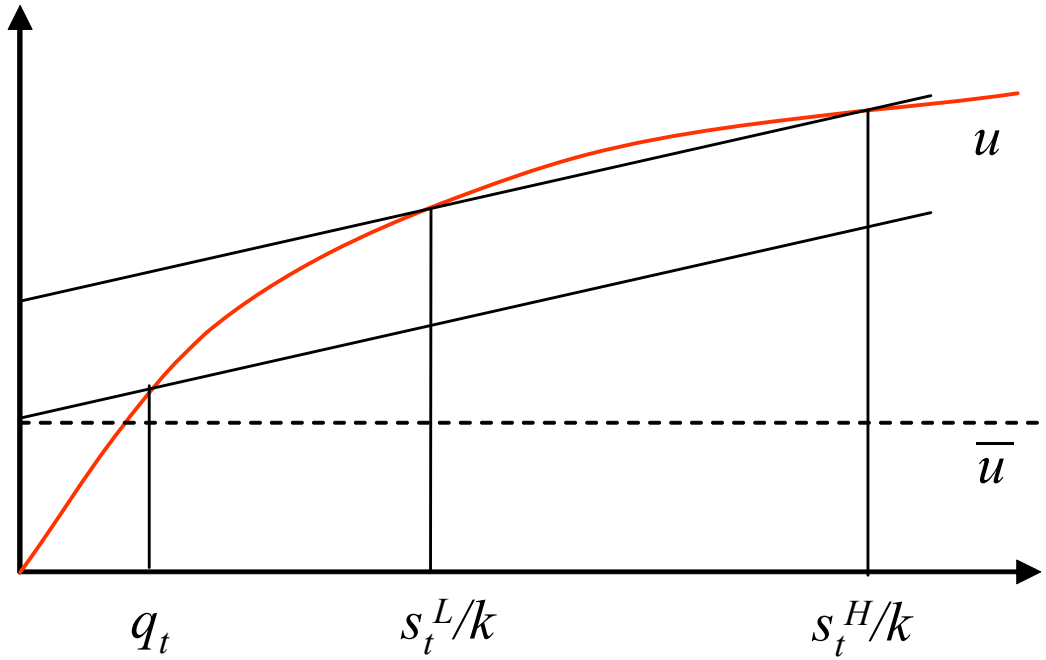
EQUILIBRIUM, CTD

- $u(q_t) = \overline{u} + q_t u'(s_t / k)$
- Buyer is compensated for delay in arrival of substitute + increasing scarcity costs during transition
- Supply increases when stock decreases.



ASYMMETRIC INFORMATION

- What happens if sellers know oil stock, but buyers don't?
- Buyers will decide on substitute development on basis of expectations
- $$u(q_t) = \bar{u} + q_t \frac{u(s_t^H / k) - u(s_t^L / k)}{s_t^H / k - s_t^L / k}$$



ASYMMETRIC INFORMATION, CTD

- Small sellers don't have to reveal their size, until the point where the stocks are so low that the transition to the substitute is in the seller's self interest.
  - At one hand, seller prefers longer spread of sales, and thus does not want to trigger substitute's development
  - At the other hand, if stocks become very low, than marginal value of resource becomes very high to seller and if current supply is much higher, ending dependence may be in interest of seller
- At this point, supplies suddenly drop and the market enters an era of acute scarcity.
- If the spread in uncertainty is large enough, there is constant risk of small sellers 'revealing their type', i.e. the seller showing that he actually only has a small stock left.

Concluding Remarks

- main lesson: oil supply may have more strategic interaction than traditional Hotelling model captures
  - buyer will have to develop substitute. The only question is when. The arrival of the substitute has a delay compared to the time when the decision is taken.
- supplies increase even though scarcity increases

- Without action: buyer's costs of continuation dependency increases over time. Seller will prevent action by compensating with higher supply

- With uncertain stocks: there is insecure supply: risk of future supply shock. Seller allows substitute to be developed only when this is in his interest: when stocks are far below mean expected level.

Climate Policy & Oil Dependency

- Climate change policy may interact with oil markets not only by capturing rents through energy/carbon taxes, but also by increasing strategic power through developing more competitive substitutes.
- Natural view of (international coordination of) Climate Change Policy as part of strategic action in oil market?
- In the long-term, is substitute innovation policy (e.g. EU policy of minimal shares for renewables) more powerful then straight emission reduction policy (EU-ETS)?
- Will less oil dependency / higher oil supplies be a secondary benefit of climate policy?