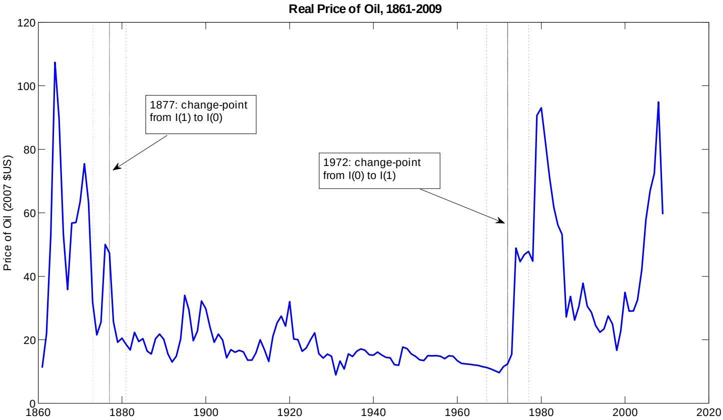
Explaining Oil Prices Through History

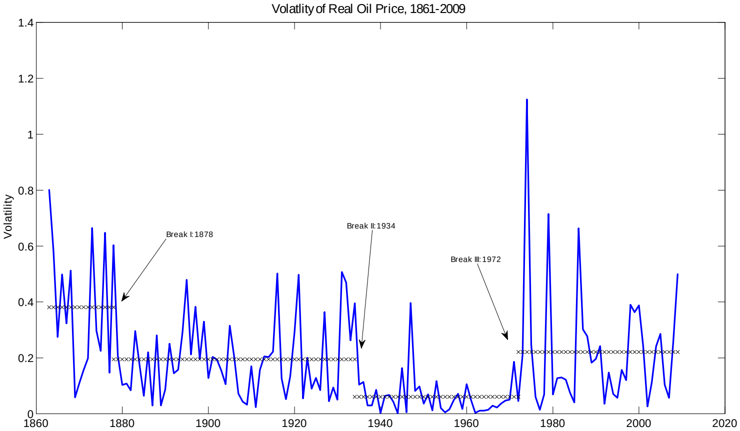
Based on "The Three Epochs of Oil" (Dvir and Rogoff)

Eyal Dvir, Boston College

June 9, 2010

- The crude oil price time series goes back to 1861.
- Stark differences in the behavior of the series across periods:
  - 1861-1877: extremely high volatility, prices very persistent and generally high
  - 1877-1972: much less volatile, prices not persistent and generally lower
  - 1972-present: again high volatility, very persistent and generally higher prices
- Change-points are estimates, moderately precise
- But evidence of change in the series very strong


Real Price of Oil, 1861-2009
Price of Oil (2007 $US)
1877: change-point
from I(1) to I(0)
1972: change-point
from I(0) to I(1)
0
20
40
60
80
100
120
1860
1880
1900
1920
1940
1960
1980
2000
2020


Volatlity of Real Oil Price, 1861-2009
Volatility
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1860
1880
1900
1920
1940
1960
1980
2000
2020
Break I:1878
Break II:1934
Break III:1972

Historical Similarities Between First and Third Periods

- Periods of intense industrialization:
  - U.S. in late 19th century (eight-fold growth of industrial output 1860 - 1900)
  - East Asia in late 20th century (21- fold growth of industrial output in China alone 1970 - 2000)
- Share of world industrial output in both cases increases significantly
- Industrialization intensive in natural resources, partly due to rising GDP per capita $\Longrightarrow$ oil market should respond

Demand Side Not Enough

- Rapid industrialization extends beyond our estimated change-points
- Very large shocks in the middle period (two world wars, post-war growth in U.S. and Western Europe, periodic Middle East crises)
- Our argument: estimated change-points signify breaks in market structure
  - Around 1878: move from transport by rail oligopoly to a long-range pipeline distribution system owned by refiners
  - Around 1972: U.S oil production operates at 100% capacity, all excess capacity is in OPEC hands
- Before 1878 and after 1972: combination of uncertain demand with controlled access to spare capacity

Why Do We Observe Concurrence of High Persistence and High Volatility?

- We write a theoretical model of the oil market:
  - Extension of canonical commodity storage model à la Deaton and Laroque (1992, 1996)
  - We introduce growth dynamics into the canonical model
  - Model accommodate both stationary and non-stationary stochastic processes
- Important assumptions:
  - Supply of oil increases with technology development
  - Cost of storage is positive and fixed

Determination of Storage

- Storage X_t and equilibrium price P_t are determined together in equilibrium:

$$X_t \geq 0 \Leftrightarrow P_t = \beta E_t[P_{t+1}] - C$$

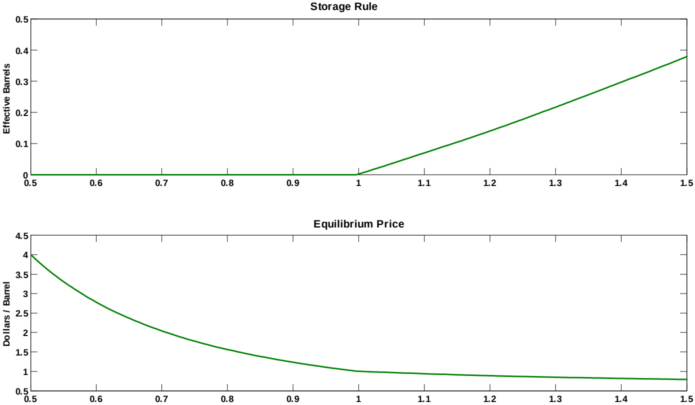
where $\beta = 1/(1+r)$ is the discount factor, $r > 0$ is the exogenously given interest rate, and $C > 0$ denotes per barrel cost of storage.

- Equilibrium price P_t must be such that there is no incentive to increase or decrease X_t.
- Alternatively, there could be a stockout:

$$X_t = 0 \Leftrightarrow P_t > \beta E_t[P_{t+1}] - C$$

- In a stockout the storage non-negativity constraint is binding.

Rational Expectations Equilibrium



Simulating A Positive Demand Shock when Income Is Stationary

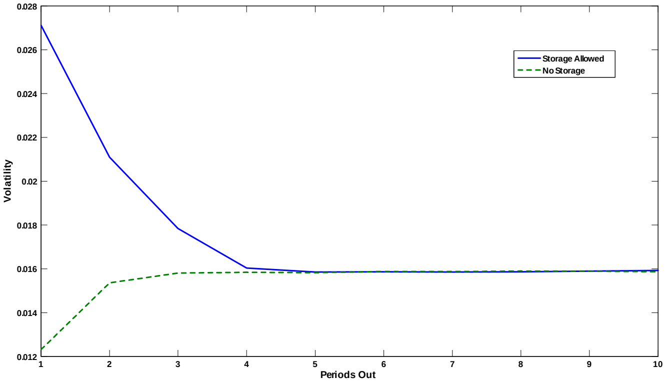
- Shock's effects on storage operate in both directions:
  - On the one hand: $P \uparrow \implies X \downarrow$
  - On the other hand, due to the shock's persistence: $E[Y] \uparrow \implies E[P] \uparrow \implies X \uparrow$
  - Former effect must dominate: in a stationary process $Y > E[Y] \implies P > E[P]$ (backwardation)
- Therefore storage drops: classic "leaning against the wind"
- As in canonical model, storage cannot increase price volatility

Simulating A Positive Demand Shock when Income Is Non-Stationary

- Shock's effects on storage again operate in both directions:
  - On the one hand: $P \uparrow \implies X \downarrow$
  - On the other hand, due to the shock's persistence: $E[Y] \uparrow \implies E[P] \uparrow \implies X \uparrow$
  - But now the latter effect must dominate: $E[Y] > Y \implies E[P] > P$ (contango)
- Therefore storage here **magnifies** the shock, increases volatility
- Opposite result to the canonical model

Role of Storage in Price Volatility

- We simulate the model with and without storage (i.e. storage constrained at zero).
- We let the model run for 30 periods, in both cases following a positive growth shock to income.
- We then repeat the process 100,000 times.
- Each time the model is run, we create a standard measure of volatility
- Simulation confirms role of storage: initial positive growth shock results in higher price volatility
- Effect lasts for several periods due to shock persistence


Storage Allowed
No Storage
Volatility
Periods Out
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
1
2
3
4
5
6
7
8
9
10

Conclusion

- Historical oil prices have gone through three periods:
  - 1861-1878: extremely high volatility, prices very persistent and generally high
  - 1878-1972: much less volatile, prices not persistent and generally lower
  - 1972-present: again high volatility, very persistent and generally higher prices
- A storage model with growth shocks can deliver concurrently high persistence and volatility
- Important role for demand uncertainty and the existence of controls on access to spare capacity
- Looking ahead, demand uncertainty likely to continue
- Can access to spare capacity be restored?
  - Energy conservation
  - Alternative energy sources
  - Canadian oil sands