

# Relationship between Technological Advance and Oil Price

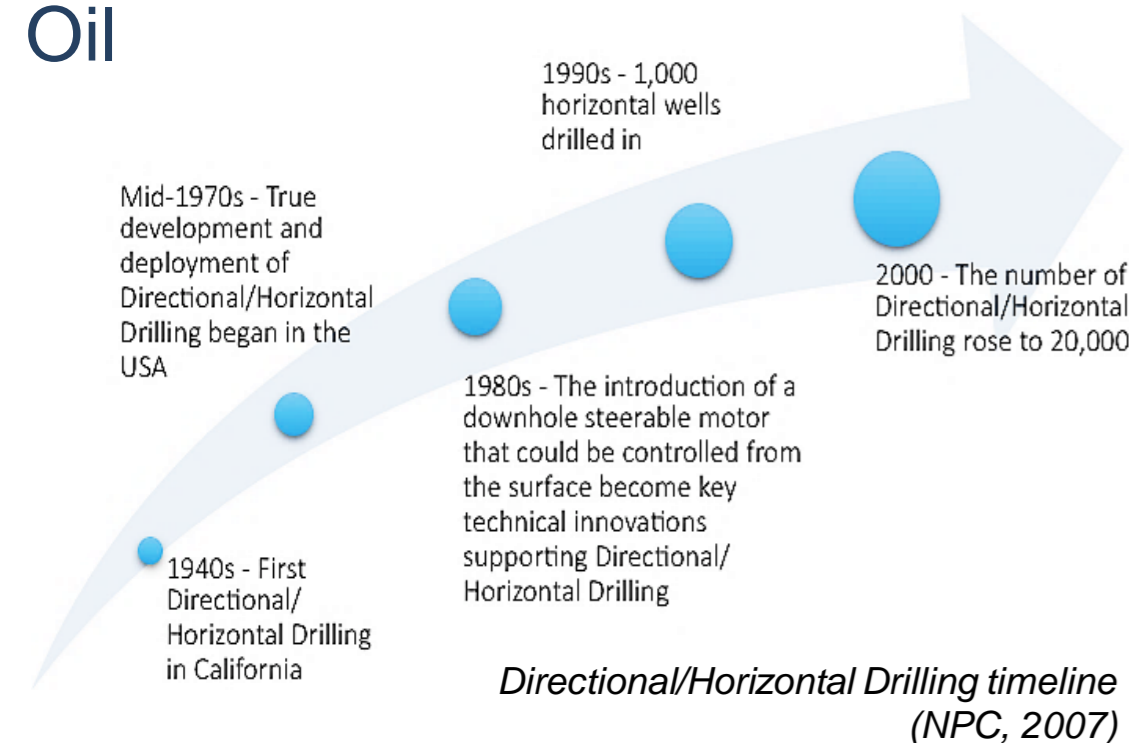
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## Introduction

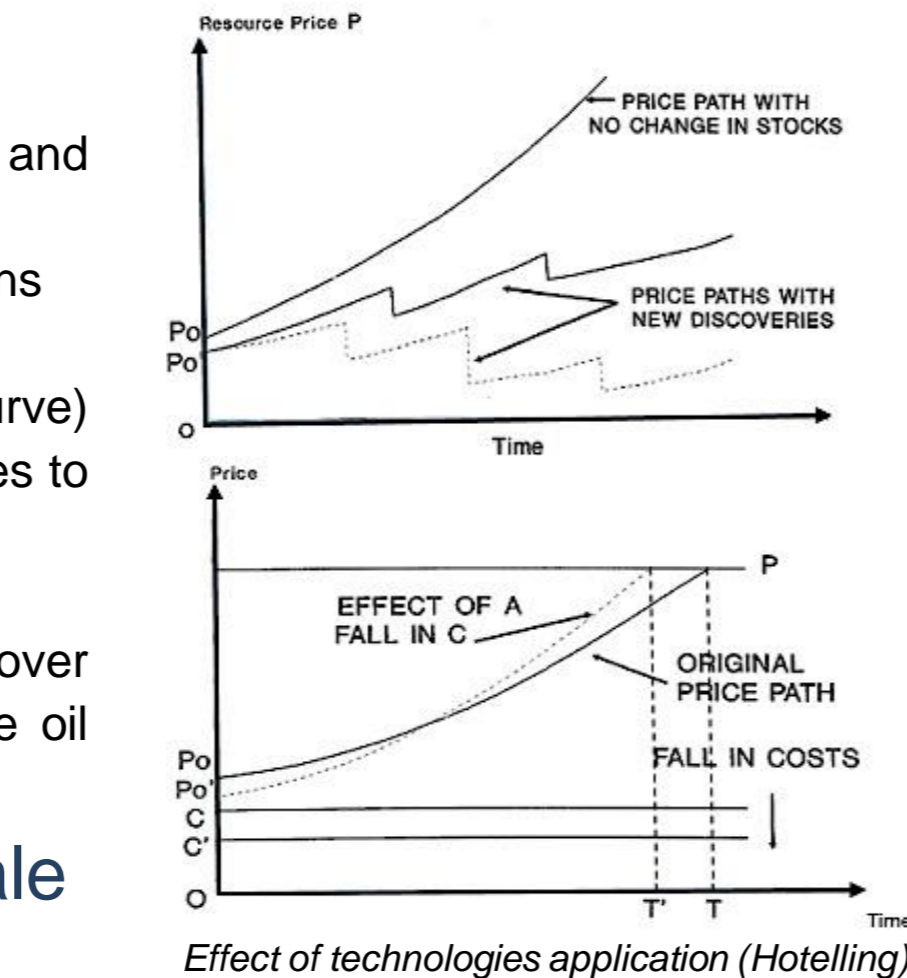
- Importance of technologies for oil exploration and production (BP, 2015)
  - Produce from previously hard to-reach formations
  - Lowering costs.
- Oil supply theories (Hotelling and The Hubbert's curve) have little explanations on the impact of technologies to crude oil supply.
- **Objective:** to understand how the technologies develop over time in petroleum industry, how it effects crude oil supply, and its relationship to oil price.

## Unconventional Oil Production: Shale Oil



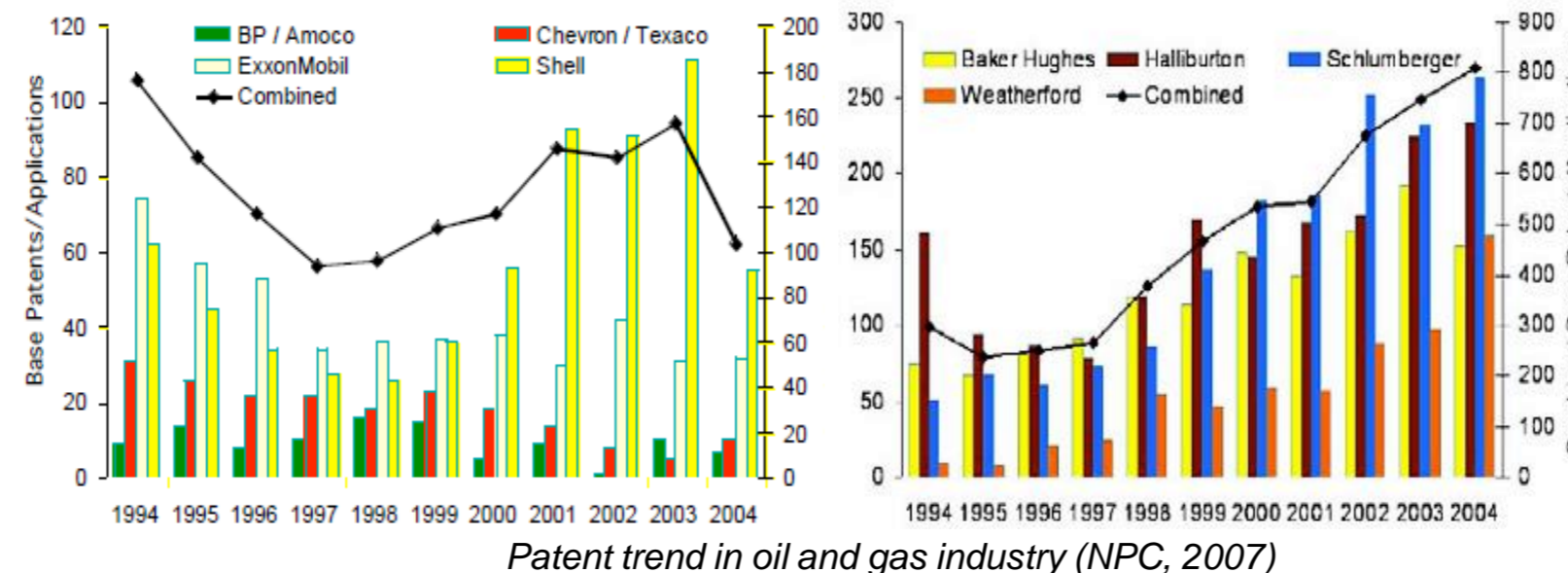
## R&D Trend

- Technology consumption depends on oil companies' spending decision, based on its revenue stream.
- Technology innovations require high/stable price as insurance. Example : higher oil prices since mid-2000s have led to a sharp rise in R&D spend and technologies innovation (NPC, 2007).  
 Note : other factor, such as government regulation might also affecting R&D spent.



- Shale oil productions require technology advancements.
- *Learning Curve* makes production processes economical over time.
- The effect of technological advance to bring oil price down is delayed due to the learning curve and risk aversion behavior in oil industry.

Note : slow technology commercialization in oil and gas industry, takes 16 years (avg.), twice as long as in medicine (NPC, 2007).



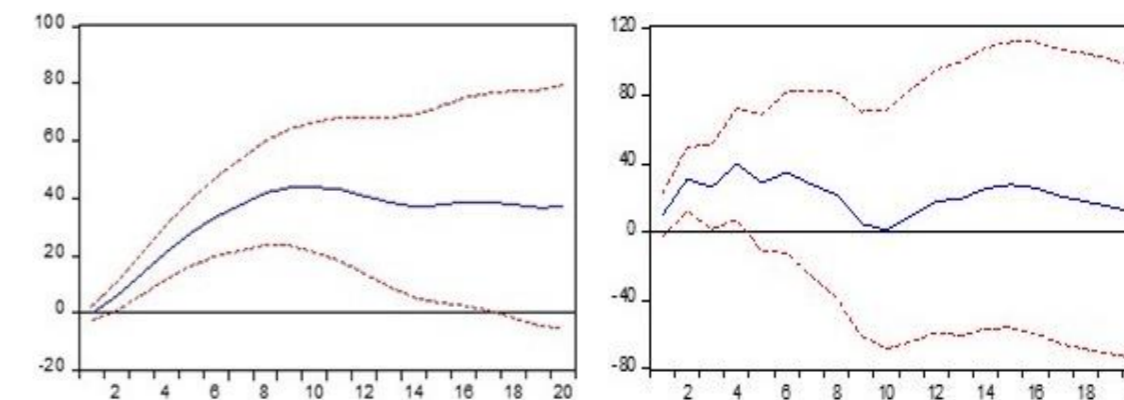
## Rig Count Data Analysis

$$Oil\ price_t = a_0 + \sum_{i=1}^p a_{1i} oil\ price_{t-1} + \sum_{i=1}^q a_{2i} oil\ production_{t-1} + \sum_{i=1}^r a_{3i} rotary\ rig_{t-1} + \sum_{i=1}^s a_{4i} workover\ rig_{t-1} + u_t \quad (1)$$

$$Oil\ production_t = b_0 + \sum_{i=1}^p b_{1i} oil\ price_{t-1} + \sum_{i=1}^q b_{2i} oil\ production_{t-1} + \sum_{i=1}^r b_{3i} rotary\ rig_{t-1} + \sum_{i=1}^s b_{4i} workover\ rig_{t-1} + v_t \quad (2)$$

$$Rotary\ rig_t = c_0 + \sum_{i=1}^p c_{1i} oil\ price_{t-1} + \sum_{i=1}^q c_{2i} oil\ production_{t-1} + \sum_{i=1}^r c_{3i} rotary\ rig_{t-1} + \sum_{i=1}^s c_{4i} workover\ rig_{t-1} + w_t \quad (3)$$

$$Workover\ rig_t = d_0 + \sum_{i=1}^p d_{1i} oil\ price_{t-1} + \sum_{i=1}^q d_{2i} oil\ production_{t-1} + \sum_{i=1}^r d_{3i} rotary\ rig_{t-1} + \sum_{i=1}^s d_{4i} workover\ rig_{t-1} + x_t \quad (4)$$



- Impulse Responses Analysis
  - Response of rotary rig to oil price
  - Response of workover rig to rotary rig

- Methodologies:
  - Vector Autoregression Model (VAR)  
 Note: Toda and Yamamoto (1994) to tackle the possibility of integration and cointegration in variables.
  - Granger causality test & Impulse responses analysis
- Variables:
  - WTI Spot price & U.S crude oil production (EIA)
  - U.S. Rotary Rig count (Baker Hughes) → drilling technologies demand
  - U.S. Workover rig count (Weatherford & AESC) → cased-hole technologies demand (production phase).
- VAR model 15 lags is adequate.
- Granger Causality Test
  - Bi-directional causality between rotary rig count and oil production
  - None of oil production, rotary rig count, or workover rig count ganger cause oil price
  - Oil price granger causes rotary rig count and oil production, but not workover rig
  - Granger causality test flow from rotary rig count to workover rig count.

## Conclusions

1. Uncoventional oil production illustrates delay in technological advance to impact crude oil supply and price.
2. R&D trend indicates oil price impacts technology developments.
3. To approach technologies demand or project planning purposes might use oil price and oil production as indicator for drilling related technology and rotary rig activity for production technologies.