# “Market Power OPEC and Production (Mis)Allocation”

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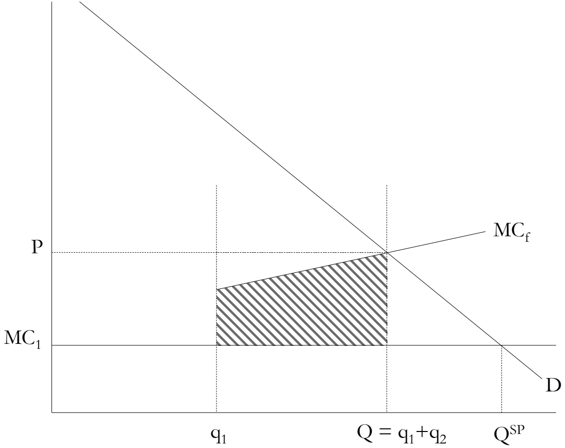
# Motivation

- Research Question: *Impact market power on the misallocation of production?*
- Approach: Data driven examination of upstream oil industry (Extraction and pre-refinery production)
- Why is this interesting?
  - Effect of market power is central to IO.
  - Both cartel activity and unilateral market power.
  - Case of aggregate implications of market power in context of misallocation literature.
  - The influence of OPEC on the world market for oil.

# Production Distortion: main approach



# Extending the static (graphical) analysis

- Oil is an exhaustible resource: we need to take the dynamics of production seriously.
  - Depletion of Reserves.
  - Constraints on extraction speed.
  - *When* a field gets extracted, not *if*.

# Literature

- Borenstein, Bushnell and Wolak 1999 AER.
- Oil Markets
  - Micro: Kellogg 2014 AER, Covert 2017 WP, Anderson, Kellogg, Salant, 2017 JPE.
  - Macro: Lutz 2009 AER
- Cartels: Marshall and Marx 2012, Asker AER 2010, Schmitz 2015 WP.
- OPEC: Cremer and Weitzman 1976 EER, Cremer, Salehi-Isfahani 1991.
- Misallocation (Harberger 1954, Harberger 1959, Hsieh and Klenow, 2009 QJE, Asker, Collard-Wexler and De Loecker, JPE 2014, + many others ).

# Main Findings

- Costs of oil production are 10 percent higher due to the OPEC cartel: about a 163 billion dollar welfare loss over a 35 year period.

# Background on Oil

- Geology and location have a big impact on costs of extraction
- Exogenous cost variation across production units unrelated to management skill rather:
  - Model (technology): onshore, offshore, shale, etc.
  - Location (geology): bedrock structure, climate, etc.
- Examples:

# West Texas

# Aasgard Norway

# OPEC Cartel

- OPEC is Algeria, Angola, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE, and Venezuela.
- OPEC is an imperfect cartel
  - Production Quota Mechanism: No monetary transfers between members.
  - Frequent instances of cheating on quotas.
  - Saudi Arabia, Kuwait, UAE usually enforce the cartel by raising production.

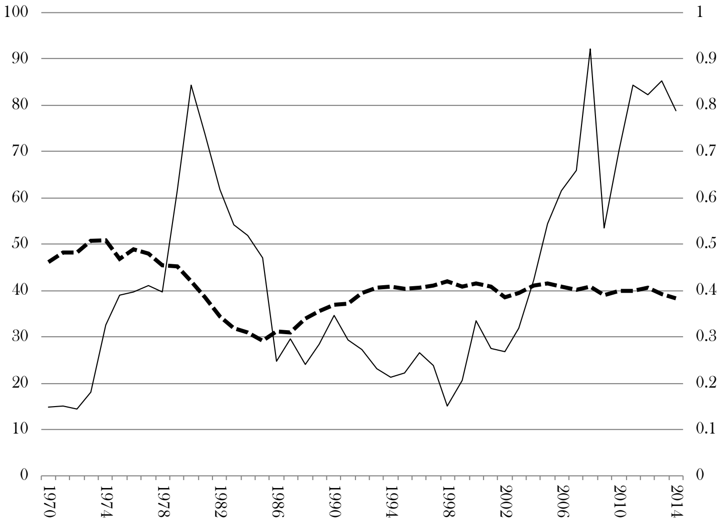
# Main Oil Producers

Table: Largest crude producers, % of global production 1970-2014

| OPEC | | Non-OPEC | |
|---|---|---|---|
| Saudi Arabia | 11.8% | United States | 14.4% |
| Iran | 5.4% | Russia | 13.0% |
| Venezuala | 3.8% | China | 4.1% |
| UAE | 3.1% | Mexico | 3.7% |
| Nigeria | 2.8% | Canada | 3.3% |
| Iraq | 2.7% | UK | 2.4% |
| Kuwait | 2.6% | Norway | 2.4% |

Notes: Global production from 1970-2014 was 1,156 billion barrels. Collectively these 14 countries account for 85.4% of global production.

# Price and OPEC



# Data

- Rich Data on oil from Rystad Energy, a Norwegian Energy Consultancy. One of the main data suppliers in the industry (IHS, Wood Gundy).
- Field Level Information: Gulfaks South versus Ghawar Uthmamiyah.
- Data from 13,000 fields.
- Information on production, costs, reserves, technology, location.

# Summary Statistics

| Variable | mean | median | 5% | 95% |
|---|---|---|---|---|
| Field-year characteristics: | | | | |
| Production (mB/year) | 3.43 | 0.22 | 0.00 | 10.92 |
| Reserves (mB) | 99.49 | 3.71 | 0.03 | 239.78 |
| Discovery Year | 1965 | 1967 | 1911 | 1999 |
| Startup Year | 1971 | 1974 | 1916 | 2005 |
| Off-shore | 0.19 | | | |
| Costs: ($m) | | | | |
| Exploration Capital Expenditures | 0.61 | 0.00 | 0.00 | 0.41 |
| Well Capital Expenditures | 9.10 | 0.49 | 0.00 | 35.32 |
| Facility Capital Expenditures | 5.14 | 0.21 | 0.00 | 16.85 |
| Production Operating Expenditures | 10.41 | 0.46 | 0.00 | 38.47 |
| Transportation Operating Expenditures | 2.27 | 0.13 | 0.00 | 7.01 |
| SGA Operating Expenditures | 2.65 | 0.22 | 0.00 | 8.85 |

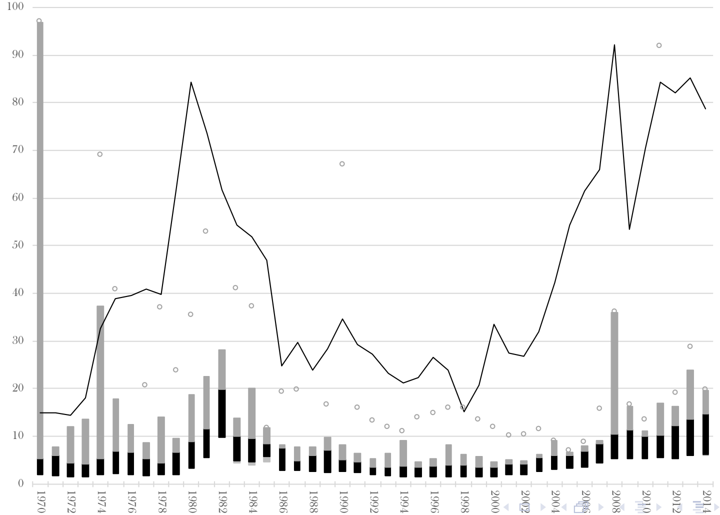
# Reserves, 2014

| | Reserves (mB) | reserves (%) | Reserves/(Annual production) (%) |
|---|---|---|---|
| Non-OPEC | 218,054 | 50 | 10 |
| OPEC | 220,561 | 50 | 19 |
| Saudi Arabia | 74,194 | 17 | 18 |

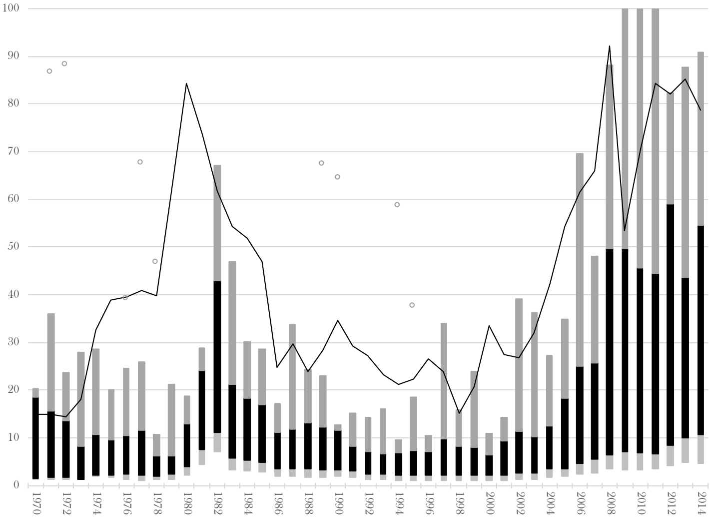
- Reserves are measured as the unextracted, but recoverable, quantity of oil remaining in the ground in a field.
  1. Descriptive stats: P50 value at an oil price of $70
  2. Counterfactual (1970 onward) sum of: i) the actual production history from 1970 to 2014, and ii) the P50 value at an oil price of $70 a barrel in 2014.

# Cost Changes over time: Saudi Arabia

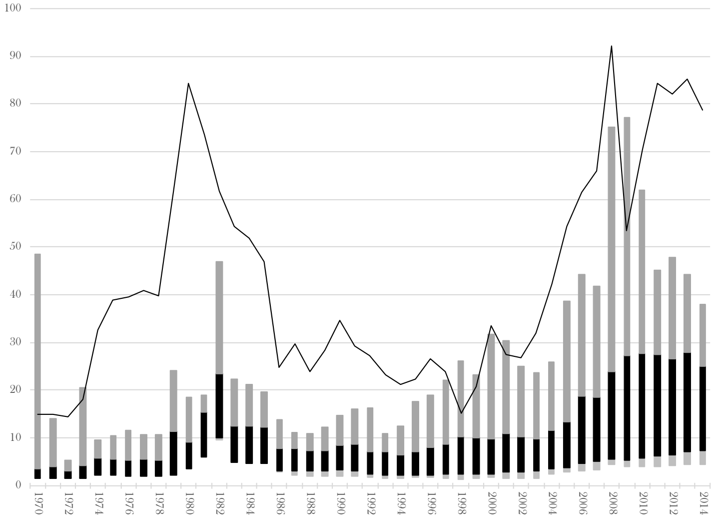
black: 95%, grey: 99% and circle: max.



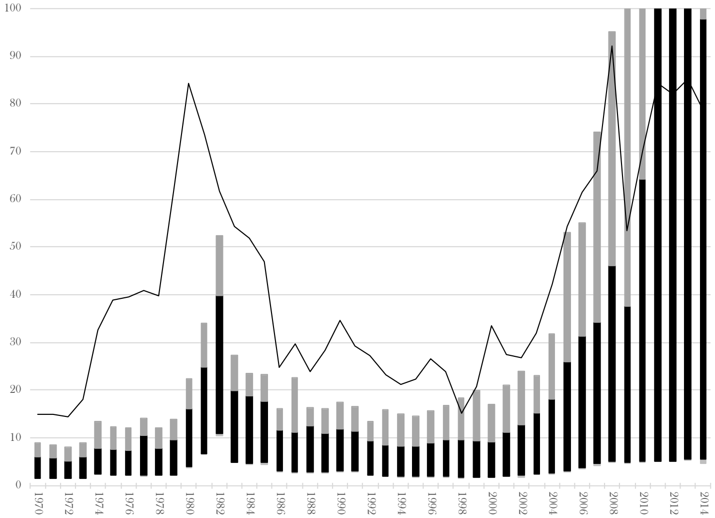
# Cost Changes over time: Nigeria



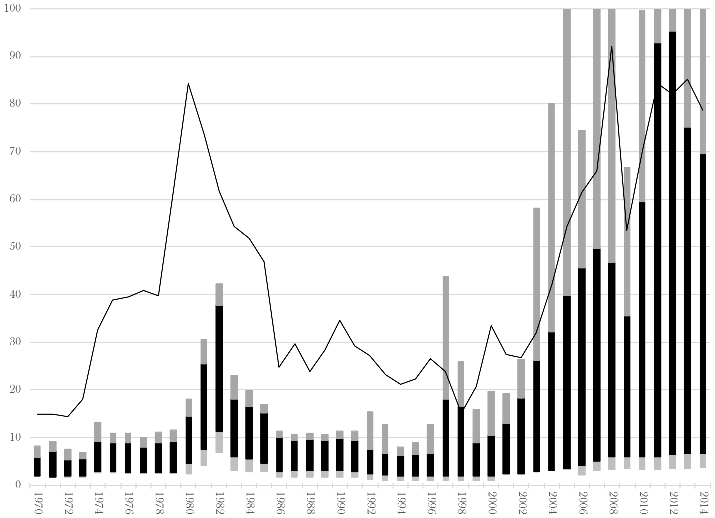
# Cost Changes over time: Russia



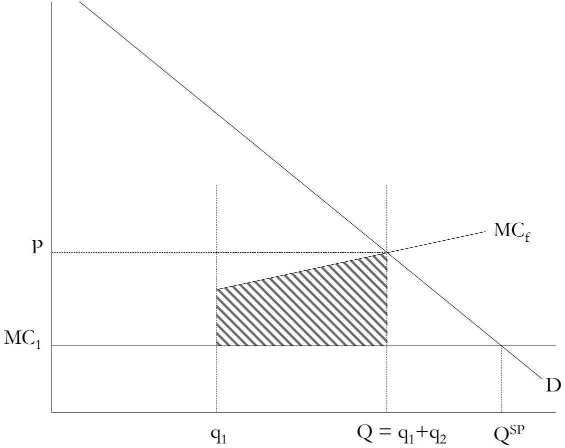
# Cost Changes over time: United States



# Cost Changes over time: Canada



# Production Distortion



# Competitive Equilibrium

- Productive Inefficiency Definition

  > *Productive inefficiency is the net present value of the difference between the realized costs of production, and the cost of production had the realized production path been produced by firms taking prices as exogenous.*

- In an exhaustible resource industry, the welfare losses come from the welfare effects of *when* to extract oil given discounting.

# Costs

- We want to take a relatively long run perspective on costs: what if OPEC had not operated over the last 20 years: mush together startup, fixed, and marginal costs.
- In the paper we build this up from a production function with input costs that vary by year.
- Marginal cost:

$$c_{ft} = c_f \mu_{st}$$

- $\mu_{st}$ is a martingale

$$E\left(\mu_{st+k} \,|\mu_{st}\right) = \mu_{st}$$

# Characterization of Equilibrium

- Homogenous product market
- Producer Solves:

$$\mathbf{E} \max_{\{q_{ft}\}} \sum_{t=1}^{T} \delta^{t-1} \left(p_t - c_{ft}\right) q_{ft}, \tag{1}$$

subject to

$$R_f \geq \sum_{t=1}^{T} q_{ft}, \quad \text{and} \quad q_{ft} > 0 \;\; \forall t \in \{1, \cdots, T\}. \tag{2}$$

- **Sorting Theorem** Proposition 1 and corollary 1: lowest cost fields are extracted first in any competitive equilibrium.

# Structural Model

- Use the sorting algorithm to compute counterfactual paths for the industry — the competitive path.
- Notice that, as in the figure, we are looking at changes in costs holding total quantity fixed.
- We will first present two types of counterfactuals:
    - Static Counterfactual: one period effects of moving to a competitive equilibrium.
    - Dynamic Counterfactuals: long run effects — all about when a barrel will be extracted, not if.

# Inputs into the Dynamic Structural Model

- Discount rate $\beta = 0.95$.
- Limits on how much oil can be extracted at once (Anderson, Kellogg, and Salant 2017). We cap the extraction rate at 10 percent of reserves.
- Fields can only be extracted after their discovery date: take the path of new discoveries as exogenous.
- We do not consider the contribution of fields that do not produce in 1970-2015, likely to understate welfare losses.
- Simulate out to 2050 — until all reserves have been depleted.
  - Demand growth set at 1.3 percent (geometric average over 1970-2015).
  - Forecasted production is optimal after 2015 (end of the data) — lower bound on welfare losses.
- Need to estimate counterfactual costs: what a field would have cost to extract in 1990 using data on costs in 2010.

# Static Distortion: as of 2014 OPEC

| Country | Actual output share | Counterfactual output share | $\Delta$ Share |
|---|---|---|---|
| Persian Gulf OPEC | 0.258 | 0.744 | 0.486 |
| Iran | 0.057 | 0.091 | 0.034 |
| Iraq | 0.029 | 0.069 | 0.040 |
| Kuwait | 0.030 | 0.155 | 0.125 |
| Qatar | 0.009 | 0.015 | 0.006 |
| Saudi Arabia | 0.133 | 0.414 | 0.281 |
| United Arab Emirates | 0.031 | 0.075 | 0.044 |
| Other OPEC | 0.135 | 0.044 | -0.091 |
| Algeria | 0.021 | 0.015 | -0.006 |
| Indonesia | 0.020 | 0.002 | -0.018 |
| Libya | 0.025 | 0.012 | -0.013 |
| Nigeria | 0.028 | 0.006 | -0.022 |
| Venezuela | 0.041 | 0.009 | -0.032 |

# Static Distortion: as of 2014 Not-OPEC

| Country | Actual output share | Counterfactual output share | $\Delta$ Share |
|---|---|---|---|
| Non-OPEC | 0.607 | 0.212 | -0.395 |
| Brazil | 0.014 | 0.001 | -0.013 |
| Canada | 0.023 | 0.006 | -0.017 |
| China | 0.045 | 0.002 | -0.043 |
| Kazakhstan | 0.010 | 0.000 | -0.01 |
| Mexico | 0.023 | 0.013 | -0.01 |
| Norway | 0.027 | 0.009 | -0.018 |
| Russia | 0.144 | 0.047 | -0.097 |
| United Kingdom | 0.022 | 0.001 | -0.021 |
| United States | 0.132 | 0.013 | -0.119 |
| Rest of the World | 0.136 | 0.044 | -0.092 |

# Welfare accounting: implementation

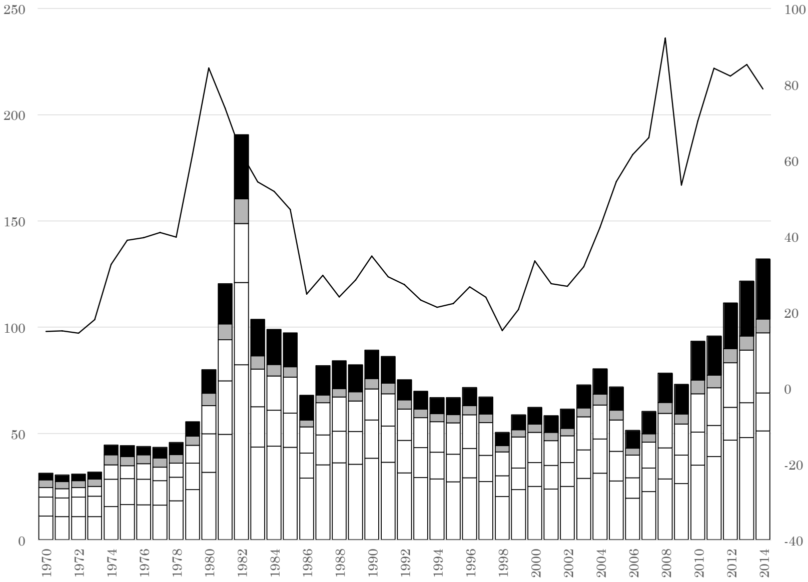
- Nested Set of Constraints:
  - Hold production in each field fixed (actual).
  - Hold production in each country fixed.
  - Hold production inside and outside of OPEC constant

Table: Static Distortion: Production Cost in 2014 in Billions of Dollars

| | |
|---|---|
| Actual | 240 |
| Optimal Country | 203 |
| Optimal OPEC | 154 |
| Optimal | 121 |

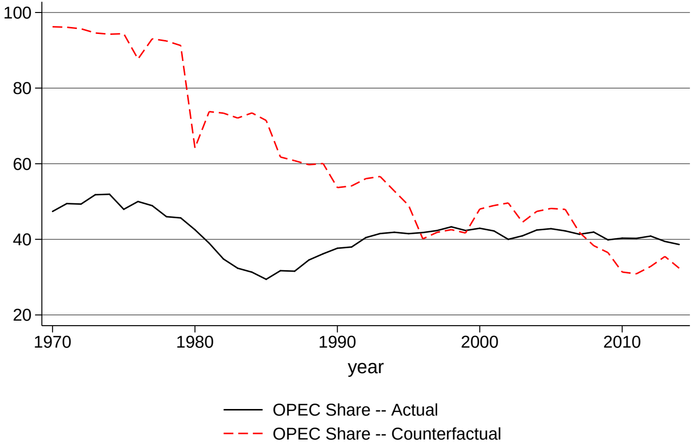
Also, can look at cartel inefficiency at intensive and extensive margin.

# Static Distortion over Time



# Dynamic Counterfactual

Simulate from 1970 to 2015: NPV starting in 1970.




Almost all the production in the 1970s is accounted for by a couple of fields: Ghawar Uthmaniyah, Greater Burgan, Ghawar Shedgum.

# Full dynamic model: results

Table 6: Dynamic counterfactual results
(NPV of costs in billions of 2014 dollars)

| | Timespan | | | |
|---|---|---|---|---|
| | 1970-2014 | | 1970-2100 | |
| Actual (A) | 2184 | (125) | 2499 | (130) |
| Counterfactual (C) | 1268 | (76) | 1756 | (79) |
| Total distortion (A - C) | 916 | (124) | 744 | (112) |
| Decomposition of total distortion | | | | |
| Within country (non-OPEC) | 329 | (80) | 284 | (41) |
| Within country (OPEC) | 192 | (46) | 157 | (72) |
| Across country (within non-OPEC) | 163 | (18) | 139 | (17) |
| Across country (within OPEC) (X) | 85 | (22) | 58 | (21) |
| Between OPEC and non-OPEC (Y) | 148 | (29) | 105 | (25) |
| Production distortion due to OPEC market power | | | | |
| Upper bound (X+Y) | 233 | (42) | 163 | (38) |
| Lower bound (Y only) | 148 | (29) | 105 | (25) |

# Conclusions

- Significant misallocation aligned with known OPEC mechanism.
  - Countries with clear market power: Gulf OPEC members.
  - Most of impact comes from timing of Ghawar (SA), Burgan (KW) and Kirkuk (IQ) extractions.
  - Misallocation rises when OPEC is known to be holding down productions and prices spike.
- Very large welfare loss , due to productive inefficiency: 160 billion USD.
- No discussion of the role of distortionary taxes or carbon externalities in this market.