"Market Power, Production (Mis)Allocation and OPEC "

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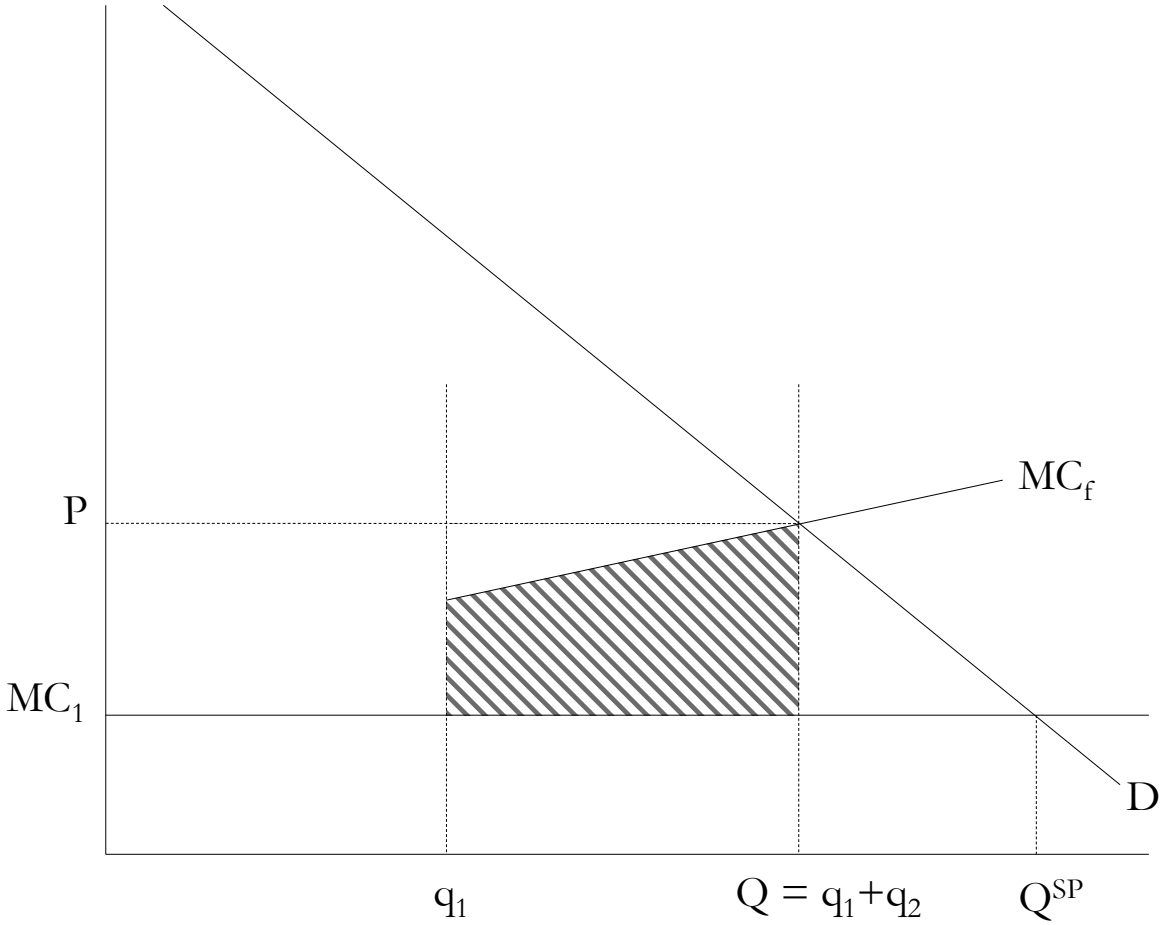
2017

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.
    - Harberger 1954: "When we are interested in the big picture of our manufacturing economy, we need not apologize for treating it as competitive, for in fact it is awfully close to being so. On the other hand, when we are interested in the doings of particular industries, it may often be wise to take monopoly elements into account.?
  - 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.

Map of Talk

- **Oil and OPEC**
- Data
- Model
- Empirical Analysis
- Conclusion

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

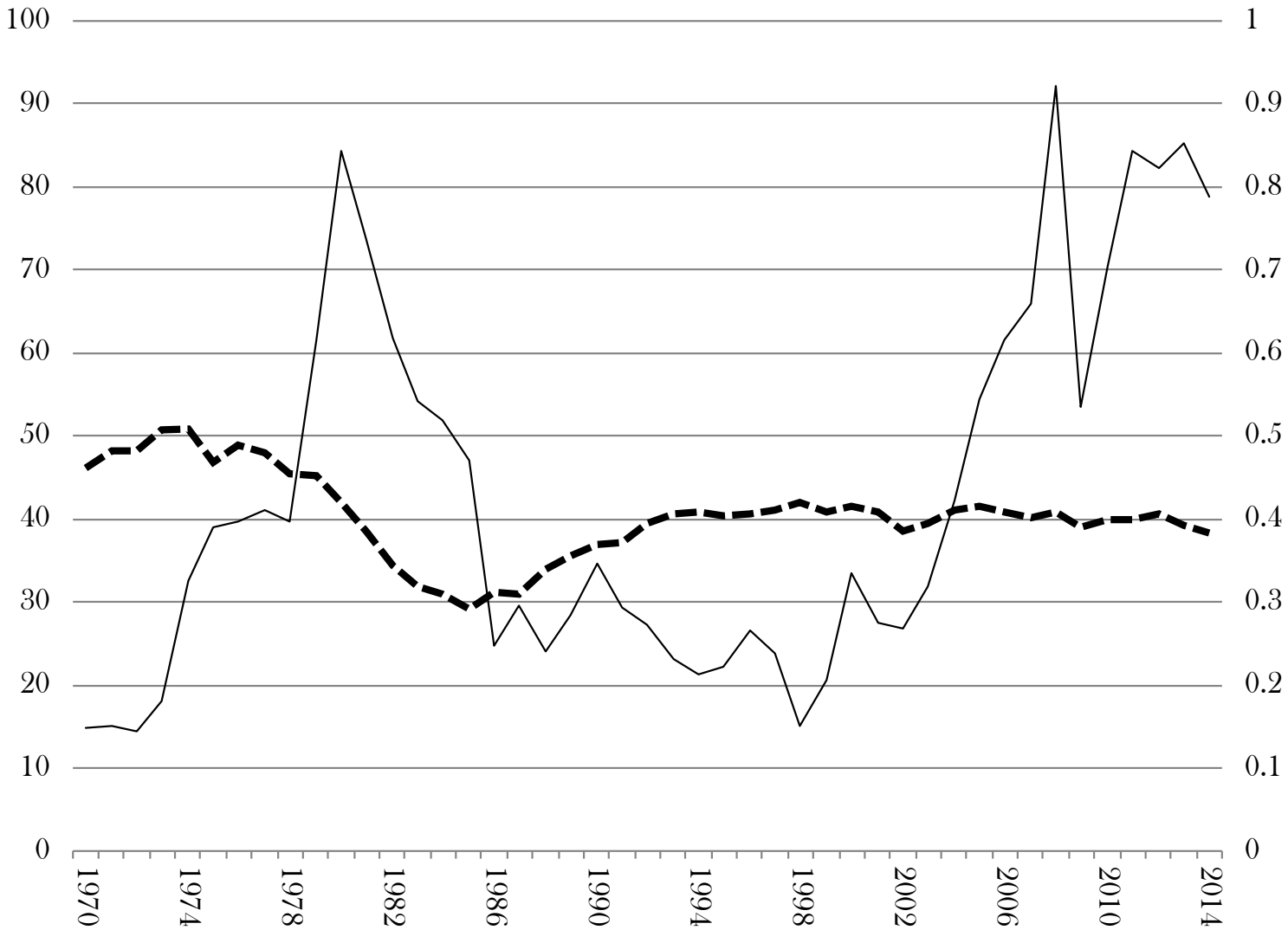
Main Oil Producers

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



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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 on 66K oil fields, of which 19K produce crude oil, of which 13K have reserve data.
- Information on production, costs, reserves, technology, location.

Data Sources

- Globally Representative Data: matches country level flows.
- Some data is great: Norway's data reported by Statoil.
- Some data is inferred from modeling: Syria, Iran.

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

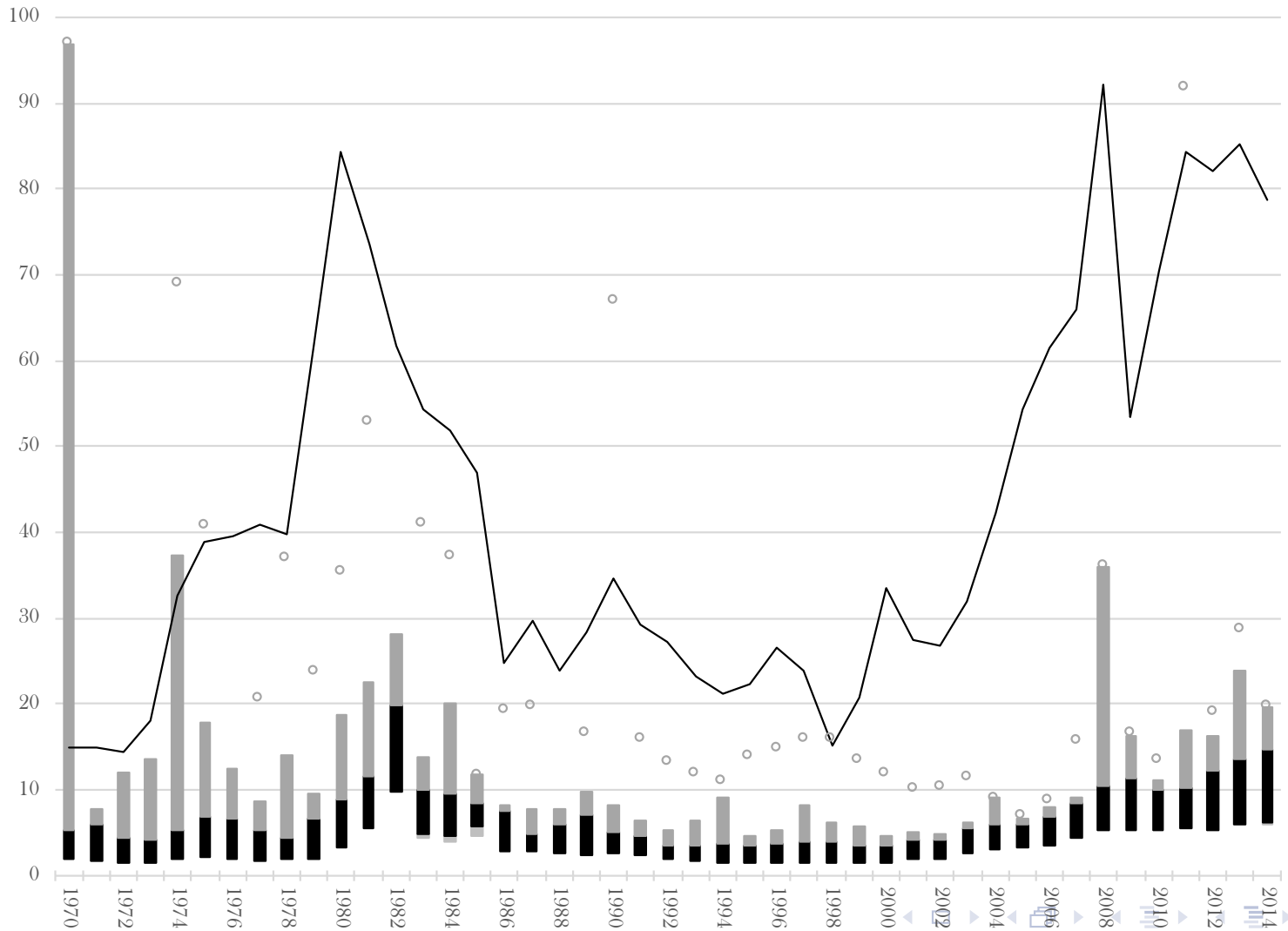
Reserves, 2014

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

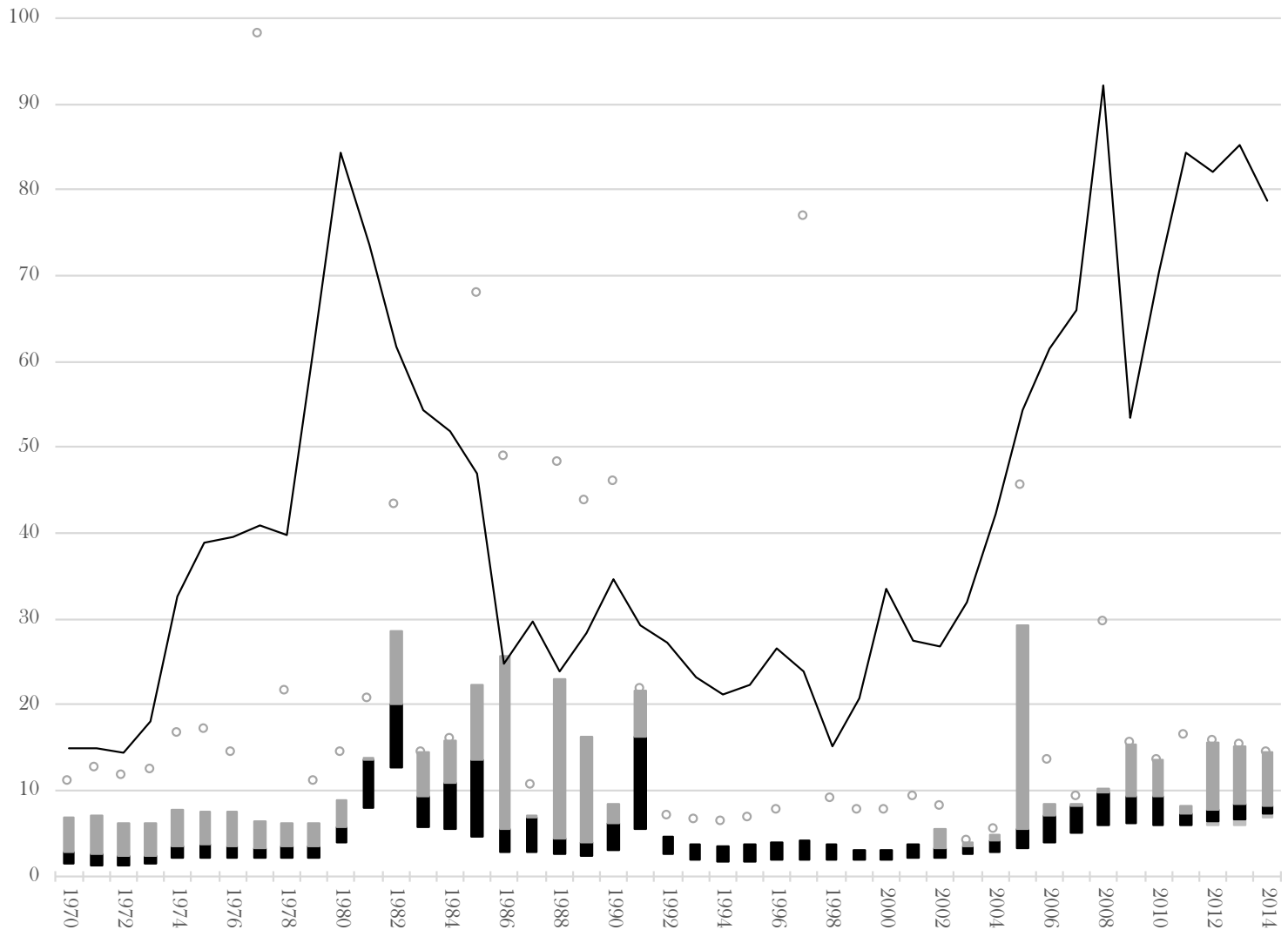
- Reserves are measured as the unextracted, but recoverable, quantity of oil remaining in the ground in a field.
  1. Descriptive stats: P50 value at an oil price of $70
  2. Counterfactual (1970 onward) sum of: i) the actual production history from 1970 to 2014, and ii) the P50 value at an oil price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

Cost Changes over time: Saudi Arabia

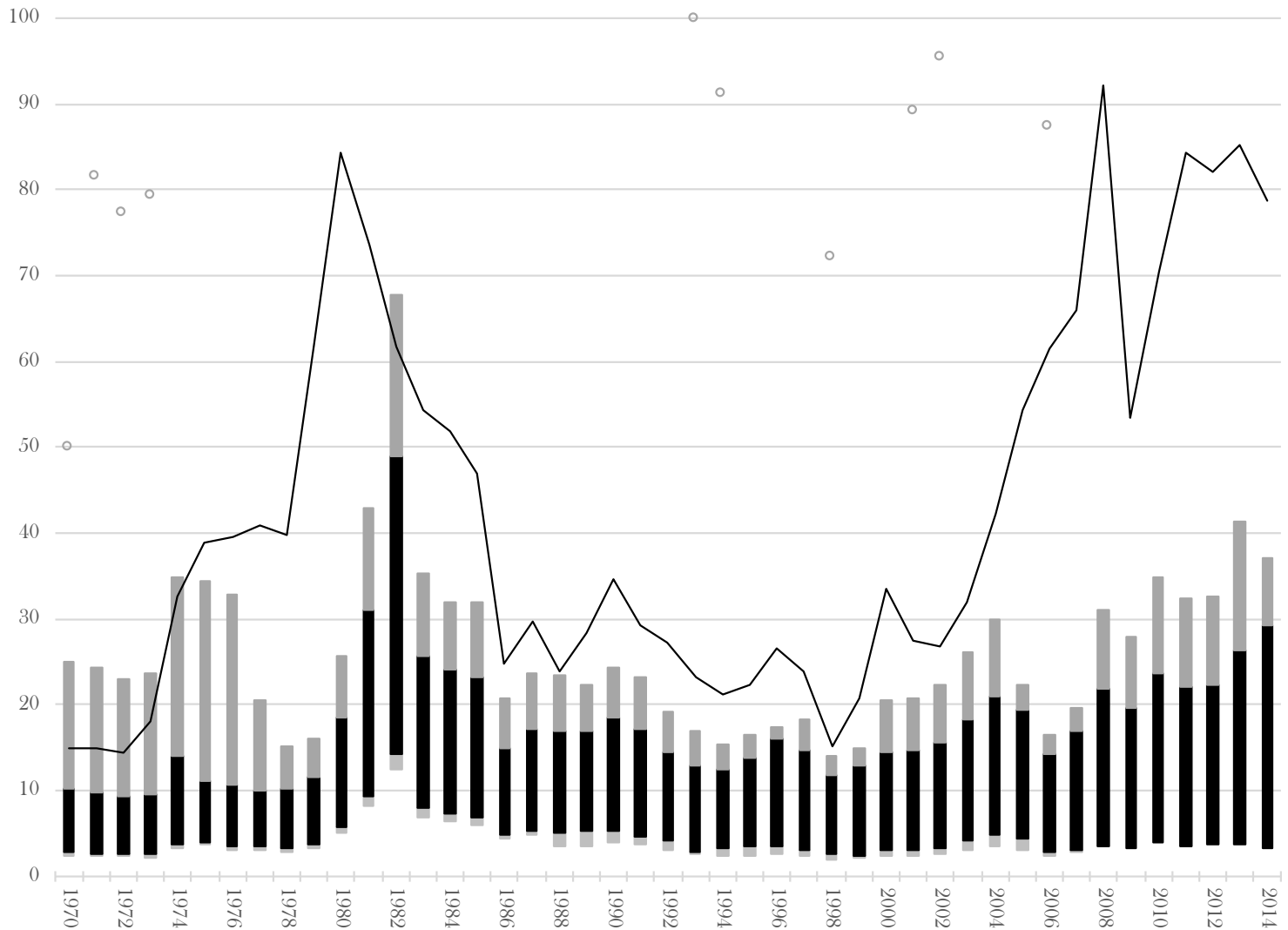
black: 95%, grey: 99% and circle: max.



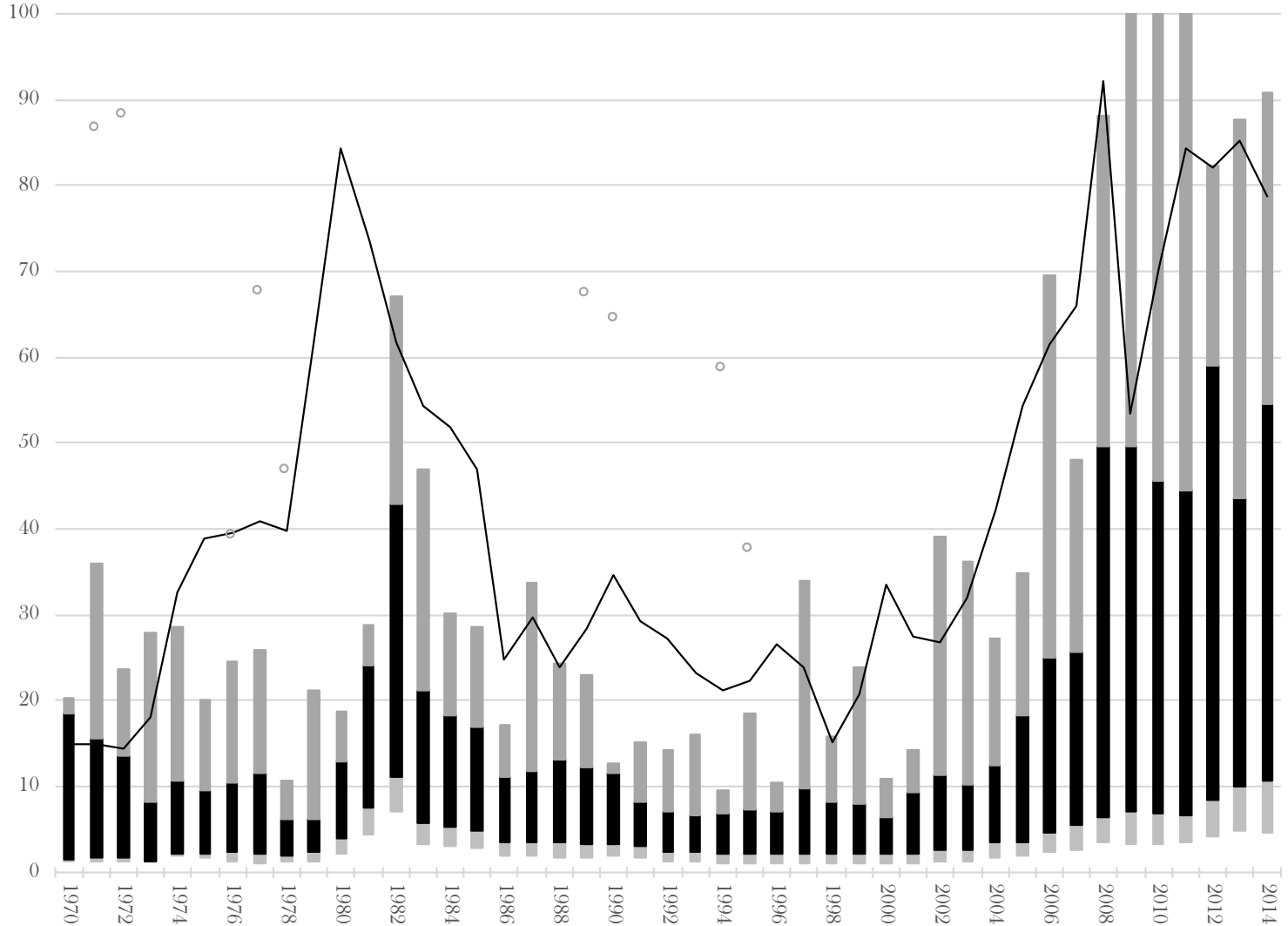
Cost Changes over time: Kuwait



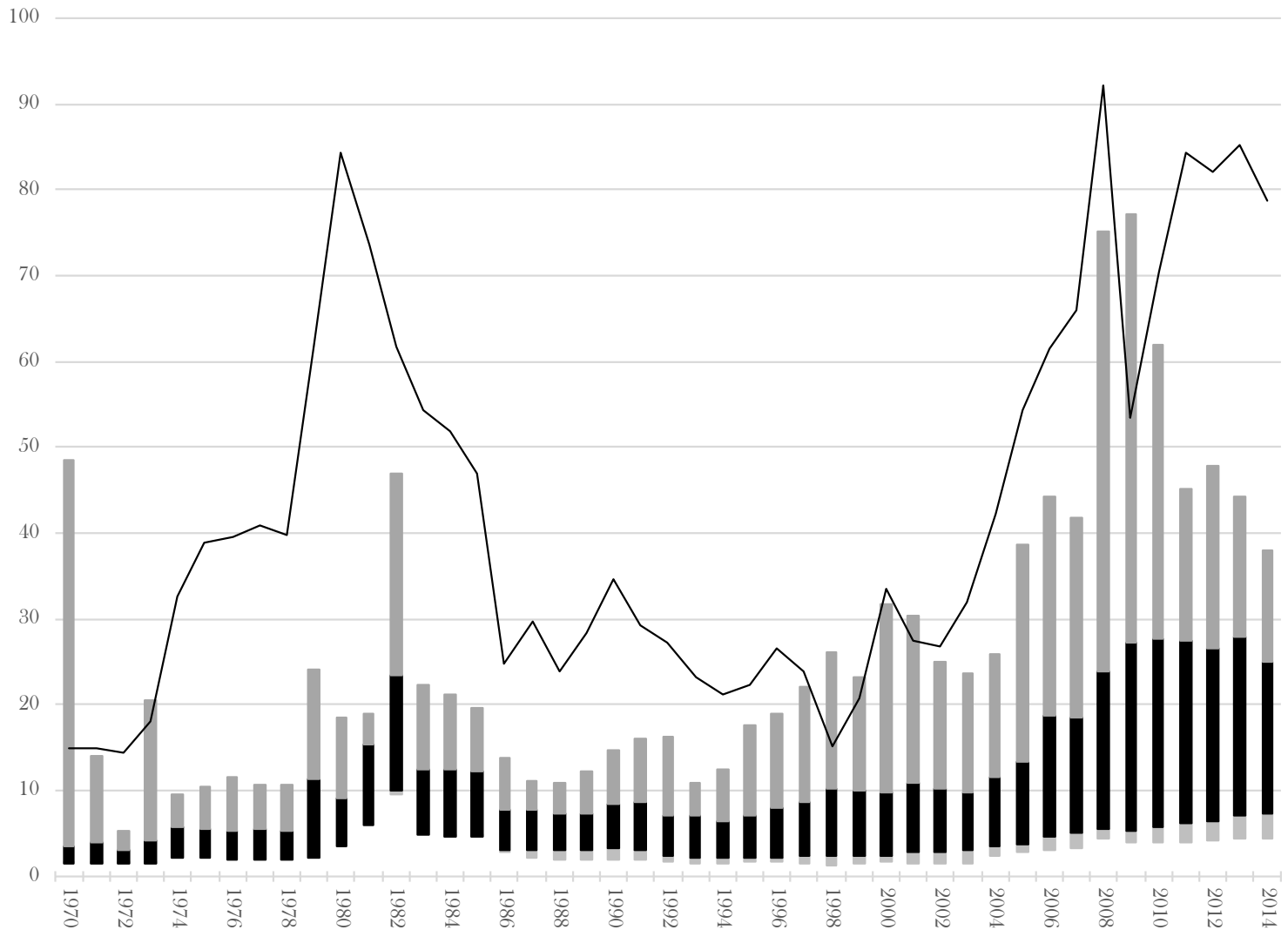
Cost Changes over time: Venezuela



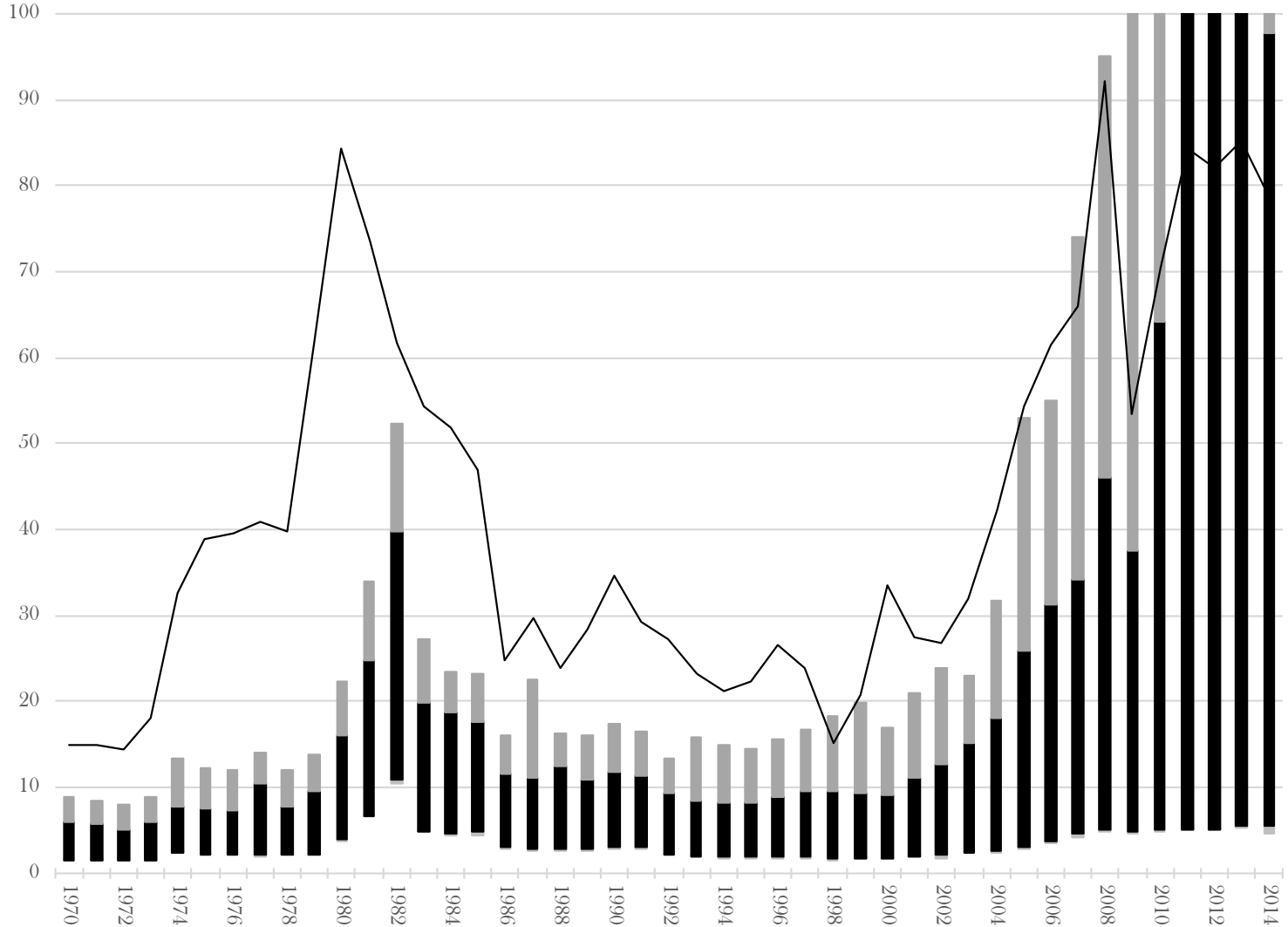
Cost Changes over time: Nigeria



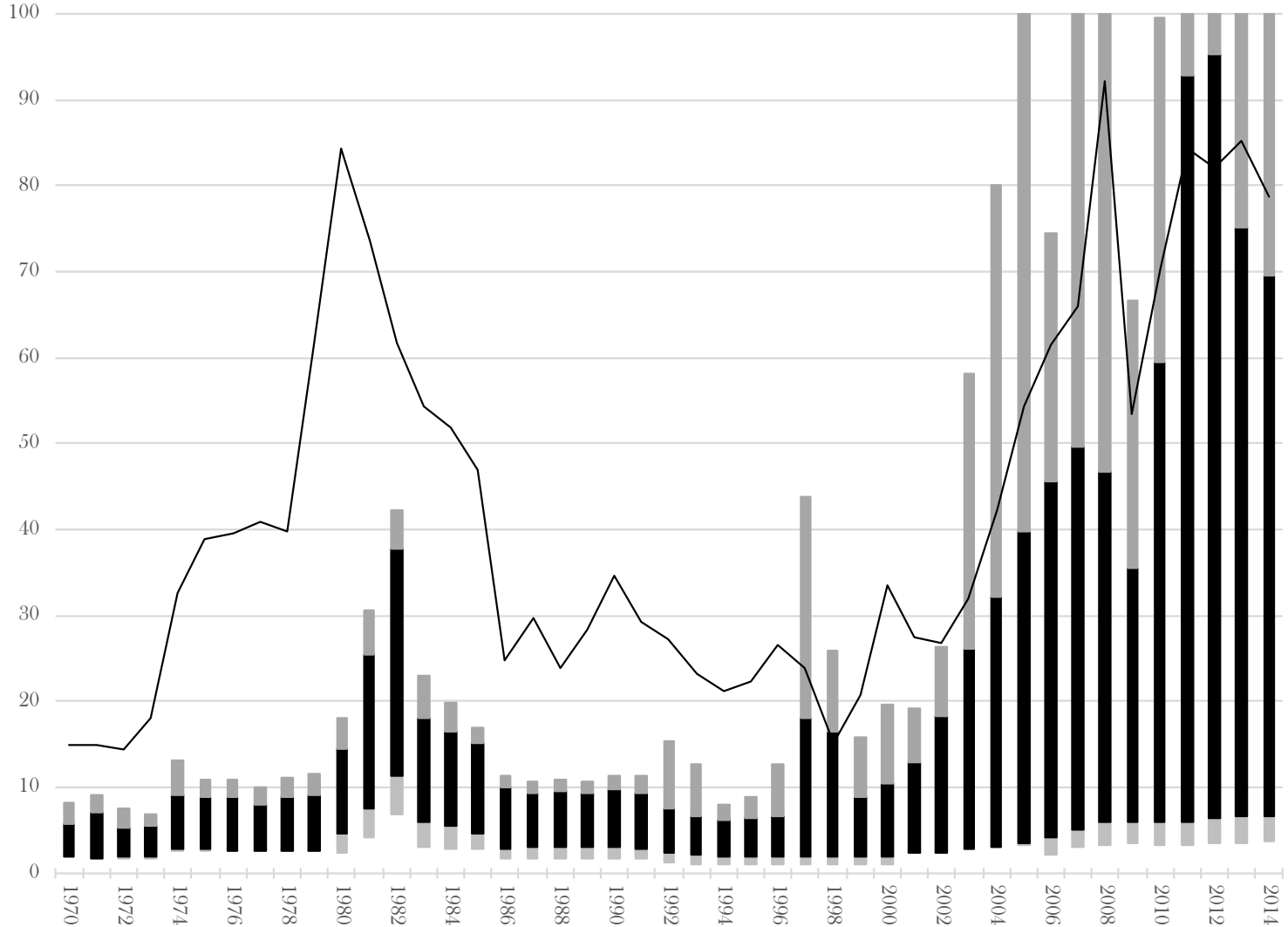
Cost Changes over time: Russia



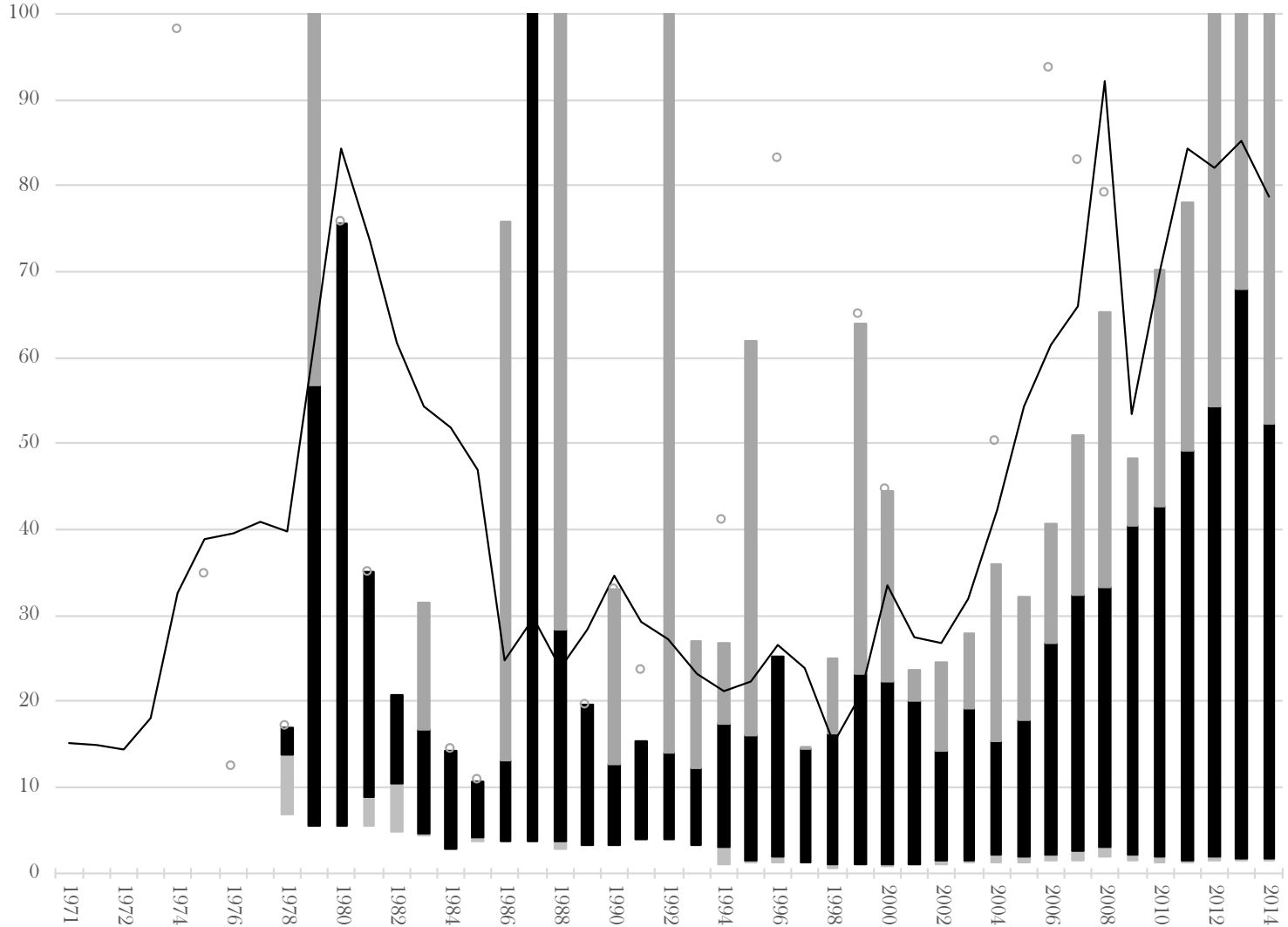
Cost Changes over time: United States



Cost Changes over time: Canada



Cost Changes over time: Norway



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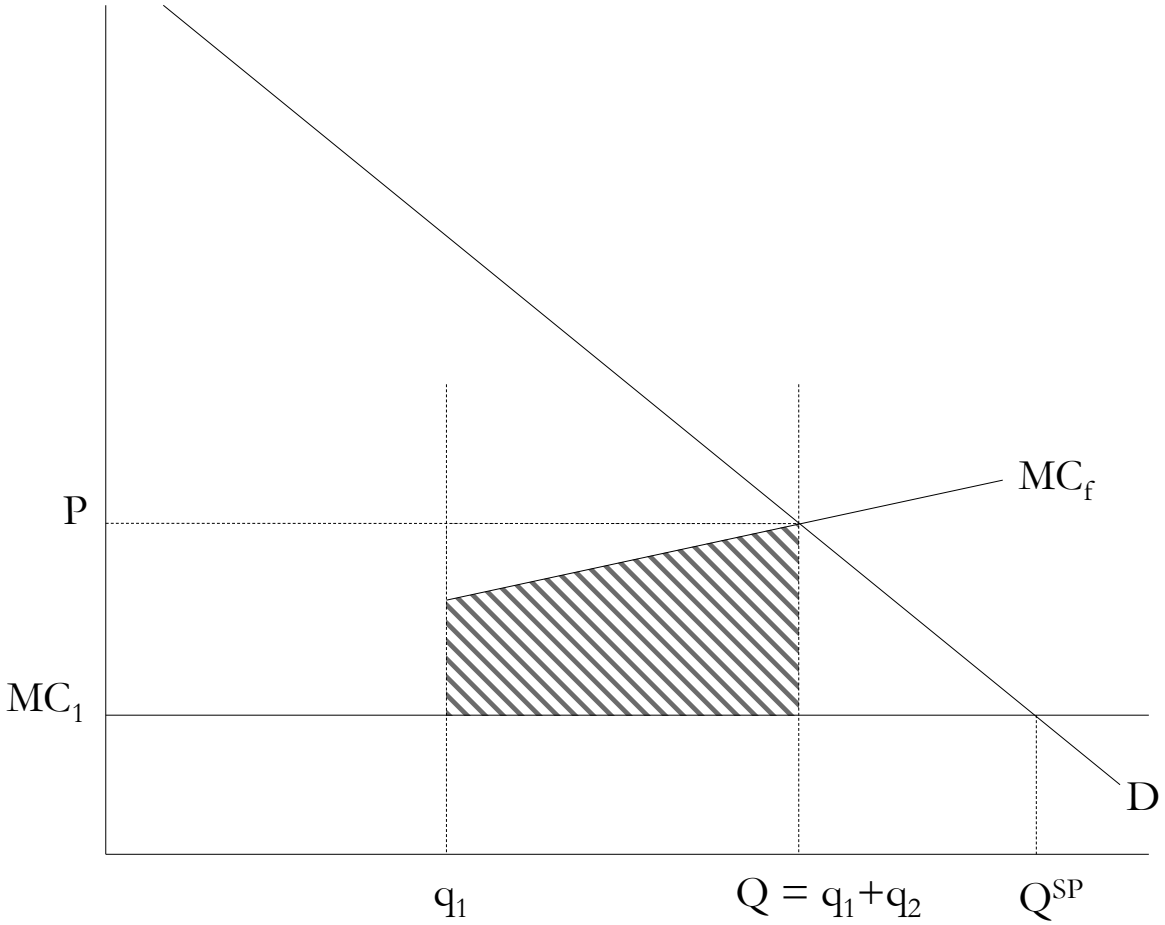
Production Distortion



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

- Leontief Production Function:

$$q_{ft} = \min\left\{\gamma_{ft} L_{ft}, \alpha_{ft} K_{ft}\right\} \tag{1}$$

- Input Prices (w_{ft}, r_{ft}) evolve over time: $\frac{r_{ft}}{\omega_t} = \mu_{st} r$ and $\frac{w_{ft}}{\omega_t} = \mu_{st} w$.
- This yields the cost function

$$\begin{aligned} C(q_{ft}) &= \left(\frac{w_{ft}}{\gamma_f} + \frac{r_{ft}}{\alpha_f}\right) q_{ft} \\ &= \underbrace{\left(\frac{w}{\gamma_f} + \frac{r}{\alpha_f}\right)}_{c_f} \mu_{st} q_{ft} \qquad (2) \\ &= c_f \mu_{st} q_{ft} \end{aligned}$$

Characterization of Equilibrium

- From previous slide, marginal cost $= c_f \mu_{st}$
- Homogenous product market
- δ be the common discount factor.
- Martingale Assumption on expectation of μ:

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

- Implication: lowest cost fields are extracted first in any competitive equilibrium.

Sorting Theorem

- Proposition 1 and corollary 1: lowest cost fields are extracted first in any competitive equilibrium.
- Sketch: take fields $\underline{F}$ and $\overline{F}$, with c_f equal to $\underline{c}$ and $\overline{c}$. By contradiction suppose that $\overline{F}$ extracted at period 1 and $\underline{F}$ extracted at period t. Then we have:

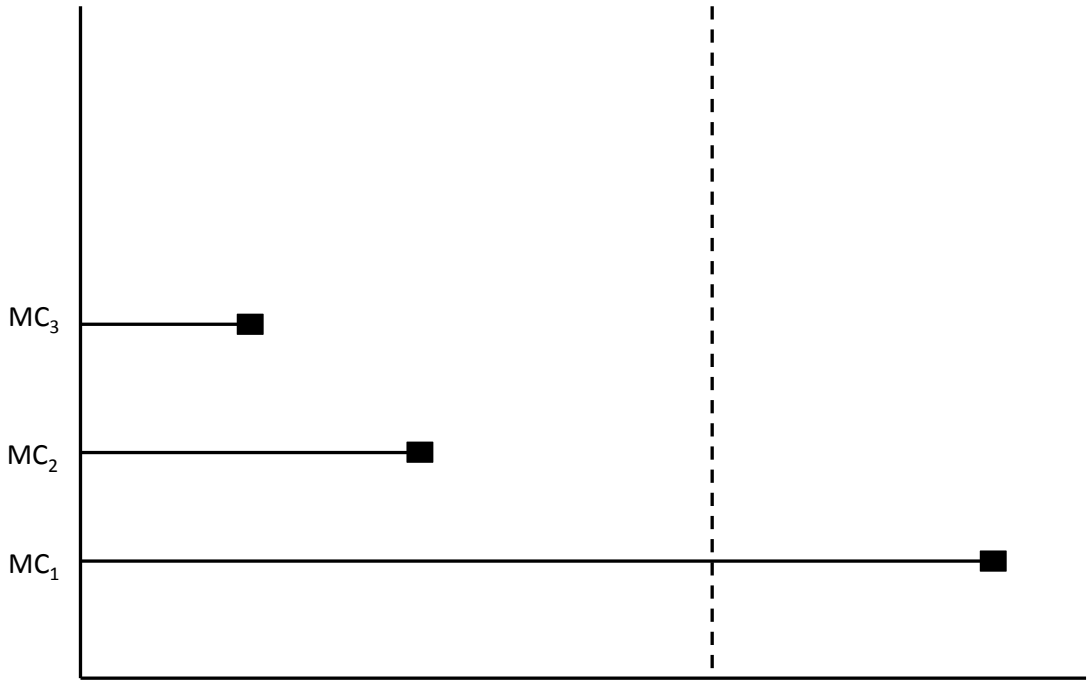
$$\delta^{t-1}(P_t - \underline{c}) \geq (P_1 - \underline{c}) \tag{3}$$

and

$$\delta^{t-1}(P_t - \overline{c}) \leq (P_1 - \overline{c}) \tag{4}$$

- Martingale means $E(c_t|c) = c$

Sorting Algorithm for Optimal Extraction Decisions



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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.

Cost Estimate

- Marginal Costs are given by:

$$c_{f,t,s} = c_f \mu_{st} \exp\left(\epsilon_{f,t,s}\right) \tag{5}$$

- First estimate μ_{st} by:
  1. Compute the average unit cost of production by year t and technology s:

$$\ln \mu_{t,s} = \sum_{f \in s} \kappa_{f,t,s} \ln c_{f,t,s}, \tag{6}$$

  where $\kappa_{f,t,s}$ is the quantity weight of a field in a given year's total output, $\kappa_{f,t,s} = \frac{q_{f,t}}{\sum_{f \in s,t} q_{f,t}}$.
  2. Recover an estimate of field-specific marginal cost shifter μ_f, allowing for measurement error, using the following regression:

$$(\ln c_{fts} - \mu_{st}) = \ln c_f + \epsilon_{f,t,s} \tag{7}$$

Static Distortion: as of 2014 OPEC

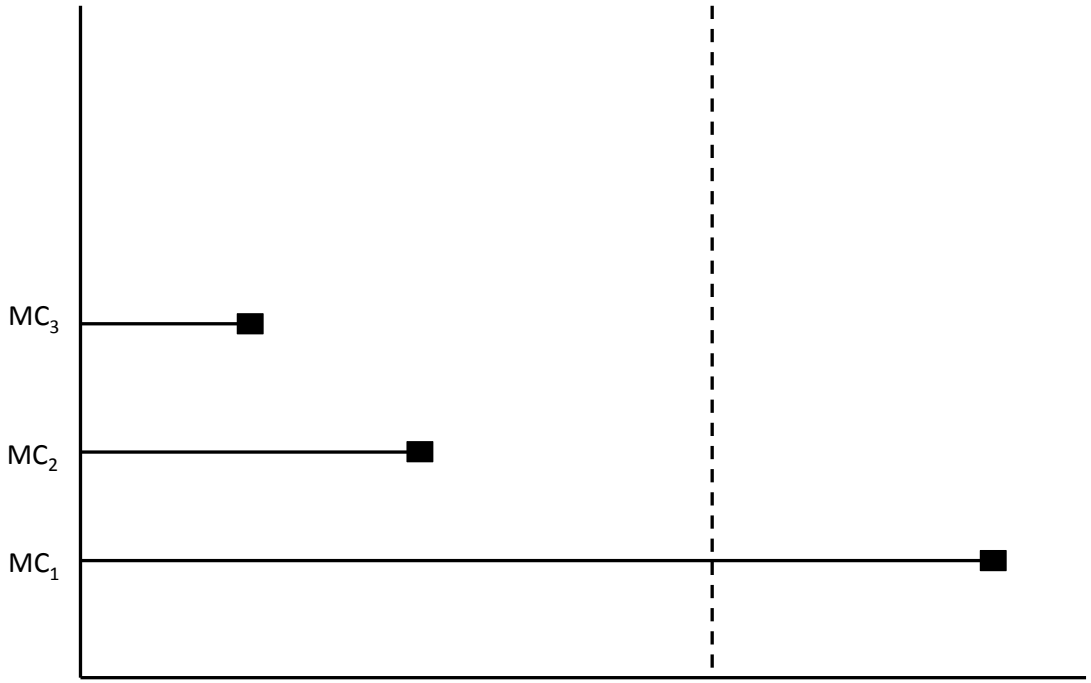
Country	Actual output share	Counterfactual output share	Δ Share
Persian Gulf OPEC	0.258	0.744	0.486
Iran	0.057	0.091	0.034
Iraq	0.029	0.069	0.040
Kuwait	0.030	0.155	0.125
Qatar	0.009	0.015	0.006
Saudi Arabia	0.133	0.414	0.281
United Arab Emirates	0.031	0.075	0.044
Other OPEC	0.135	0.044	-0.091
Algeria	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	Δ 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

Doing the welfare accounting

- Comparing the sorting algorithm to the data is too strong: encapsulates any distortion, and also measurement error, model misspecification and such.



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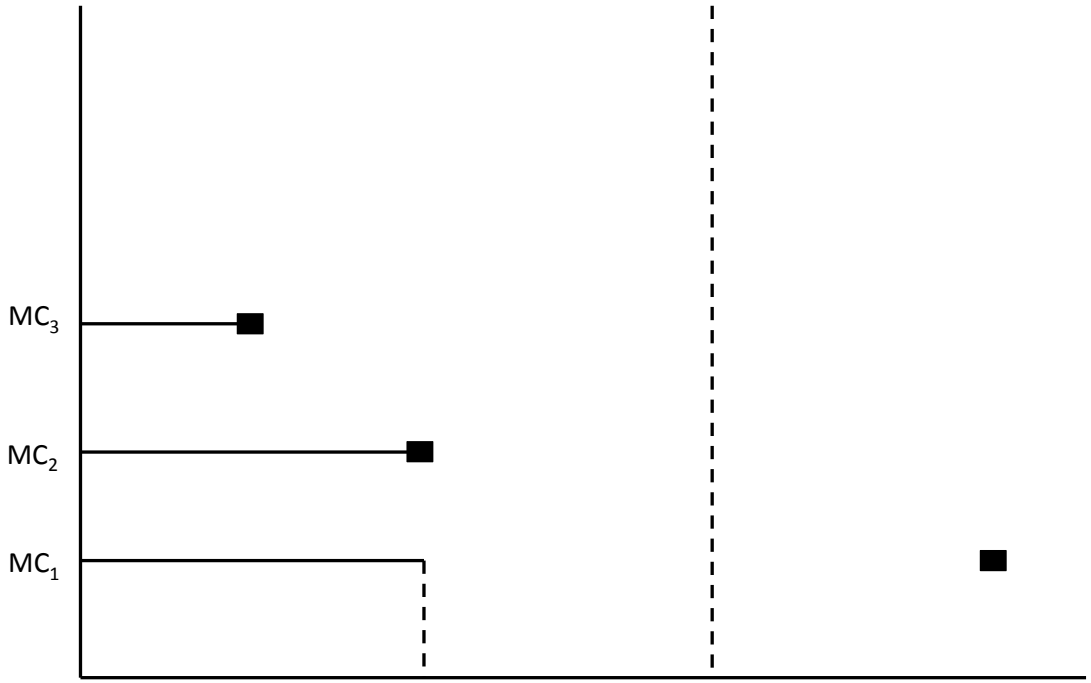

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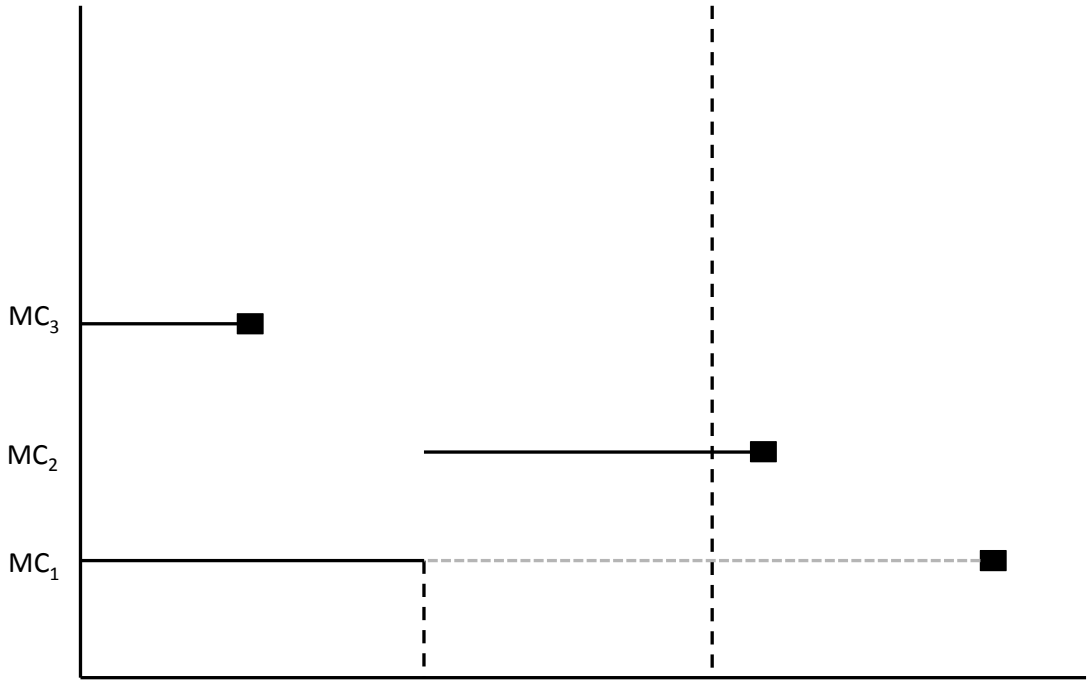

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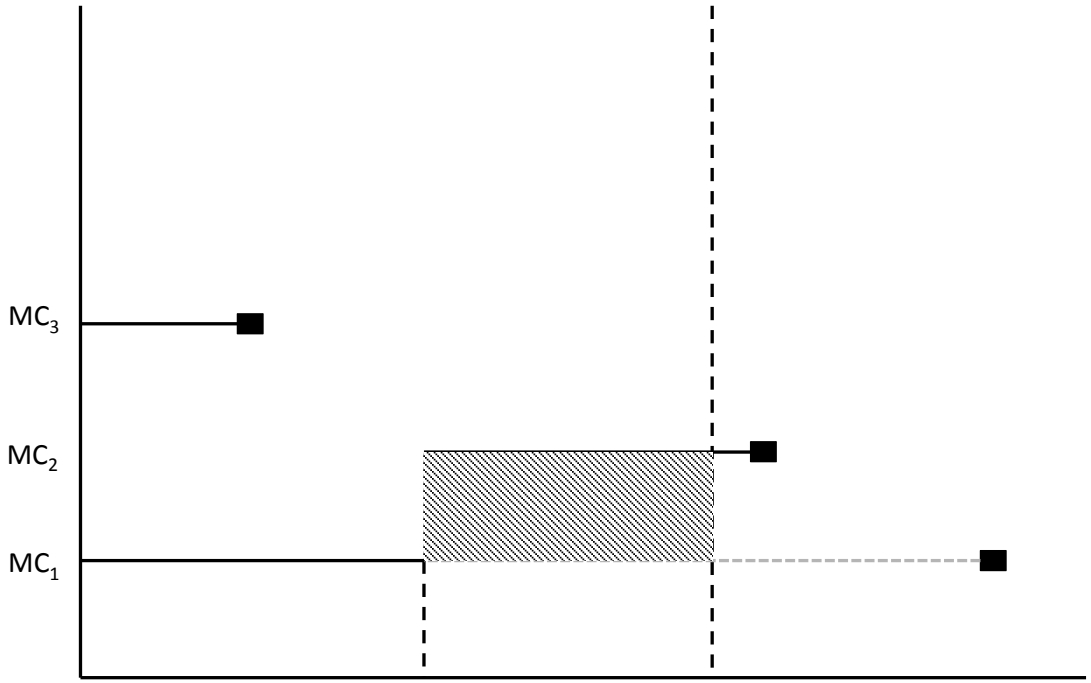

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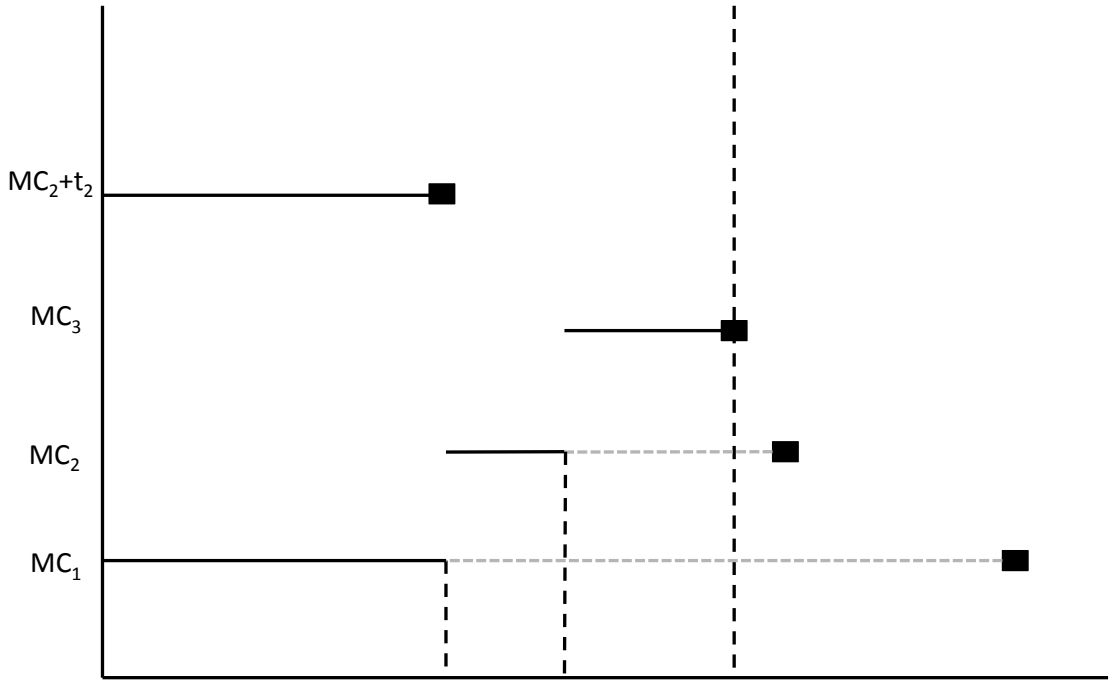

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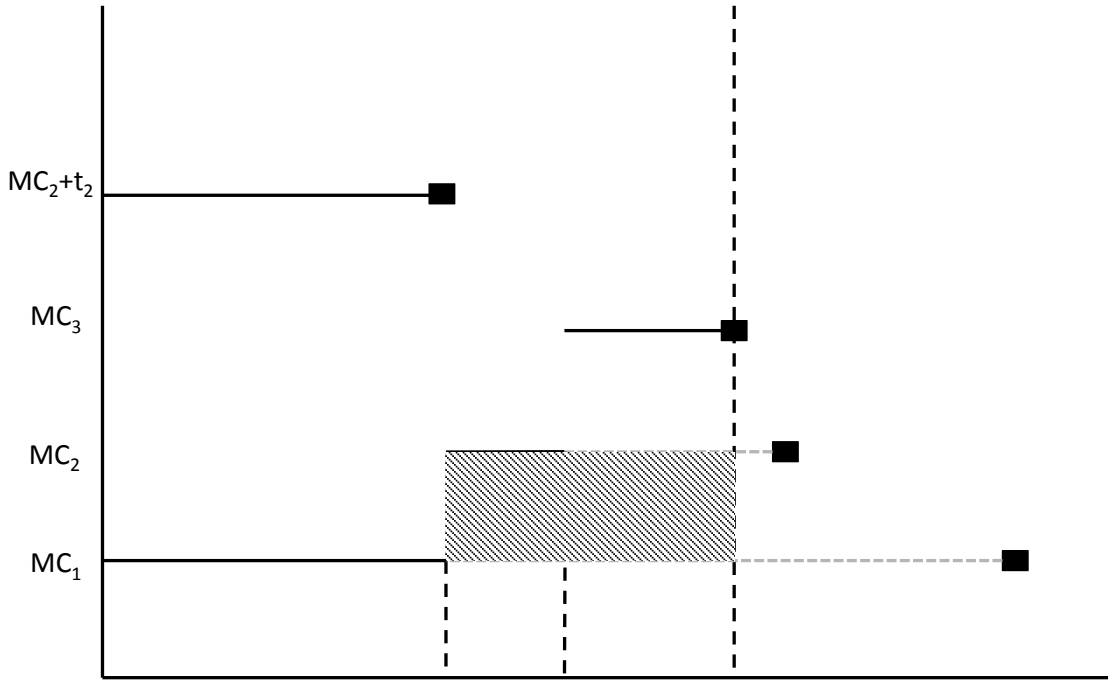

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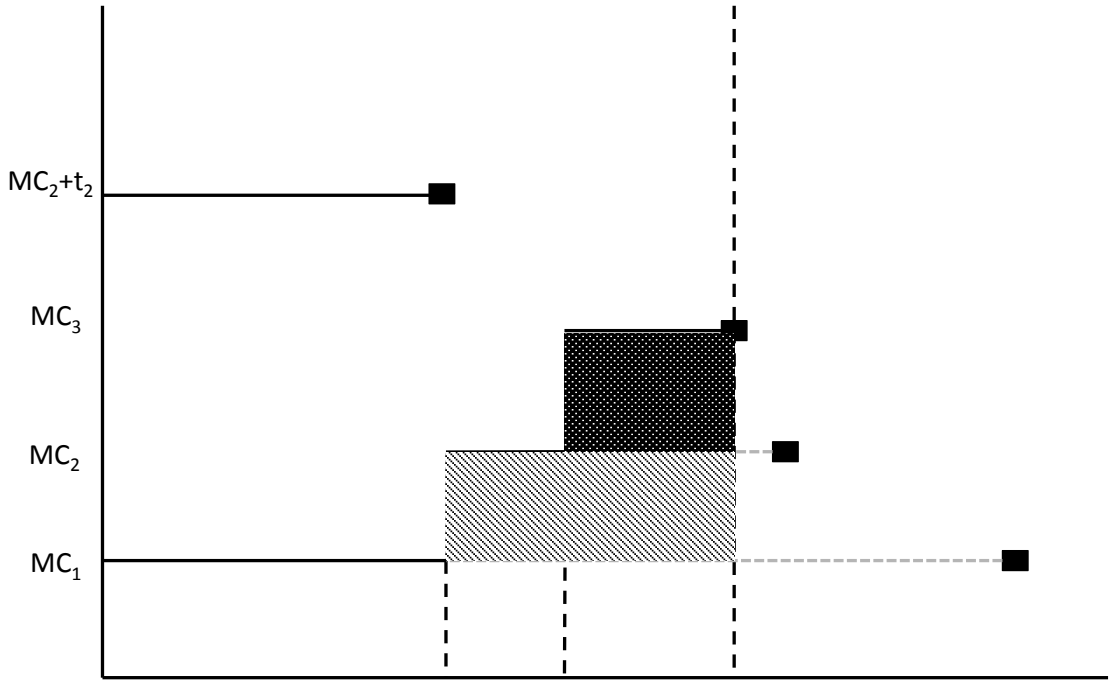


Welfare accounting: implementation

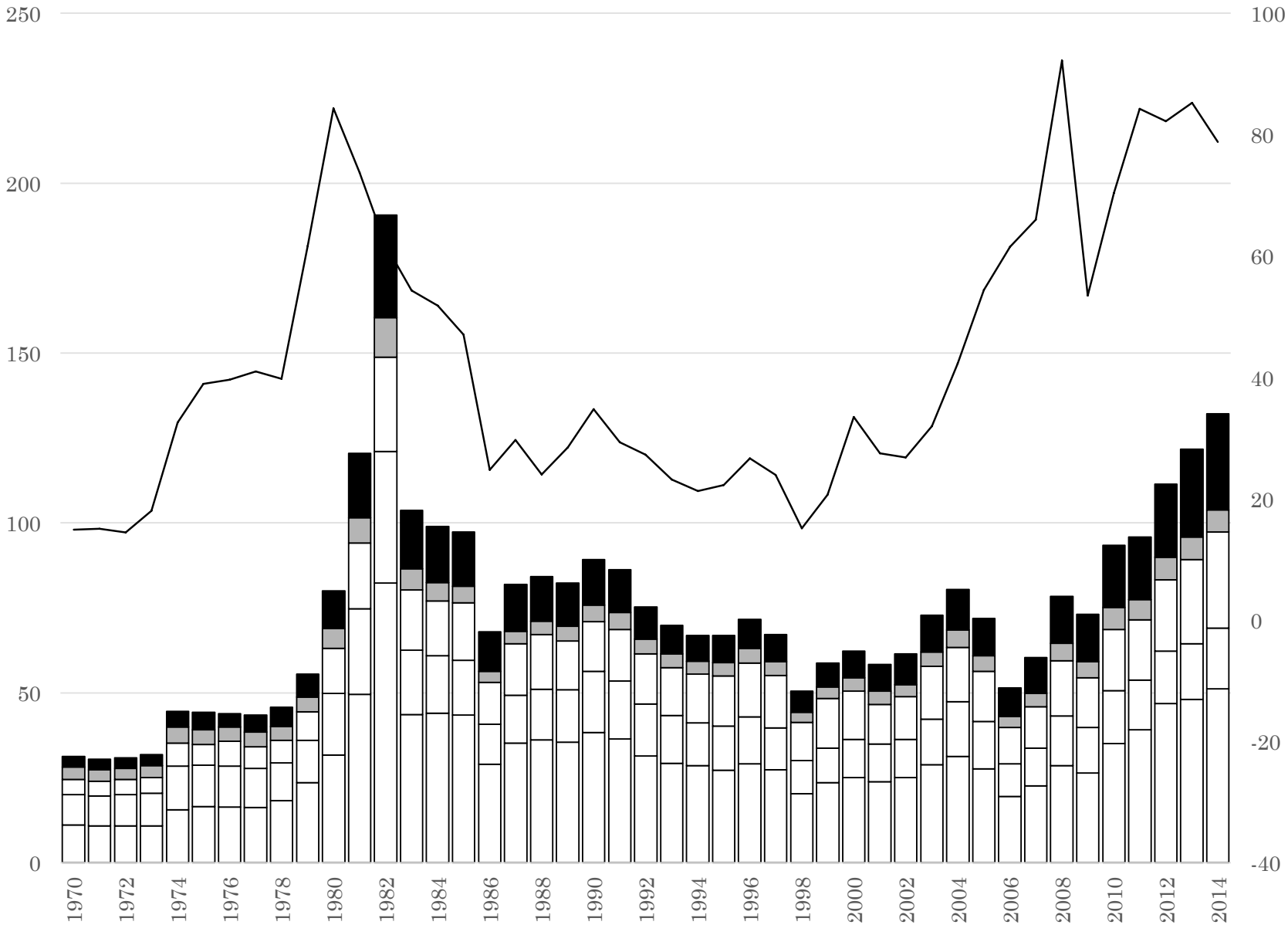
- Nested Set of Constraints:
  - Hold production in each field fixed (actual).
  - Hold production in each country fixed.
  - Hold production inside and outside of OPEC constant

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

Actual	240
Optimal Country	203
Optimal OPEC	154
Optimal	121

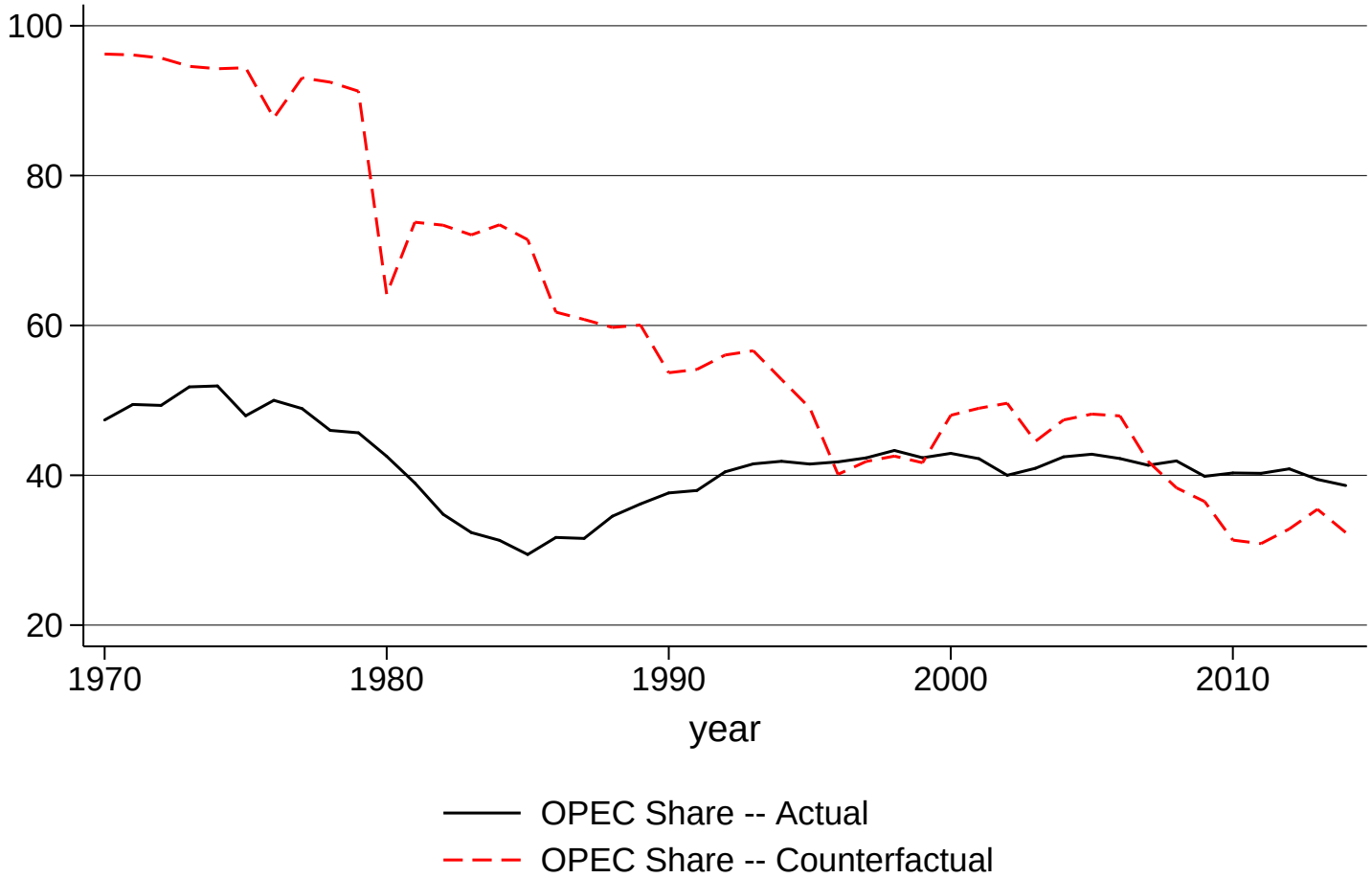
Also, can look at cartel inefficiency at intensive and extensive margin.

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)

Robustness of Counterfactuals

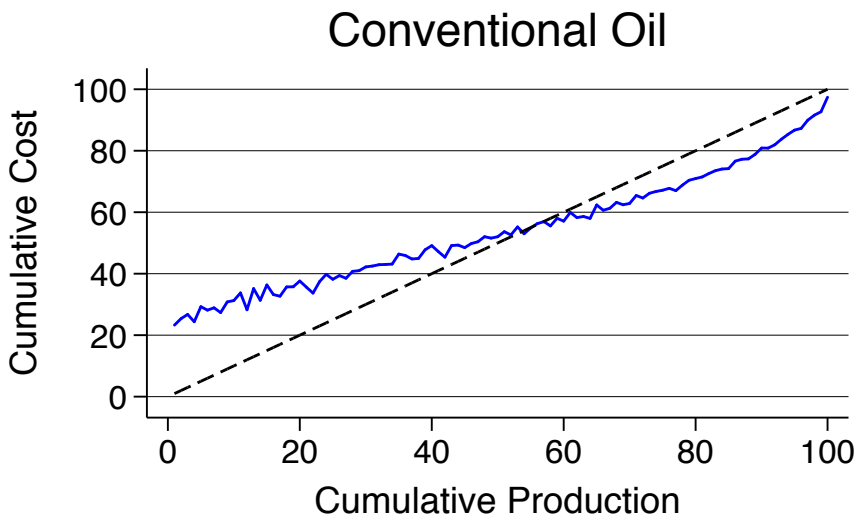
Table 9: Dynamic counterfactual results, conditional on inferred wedges

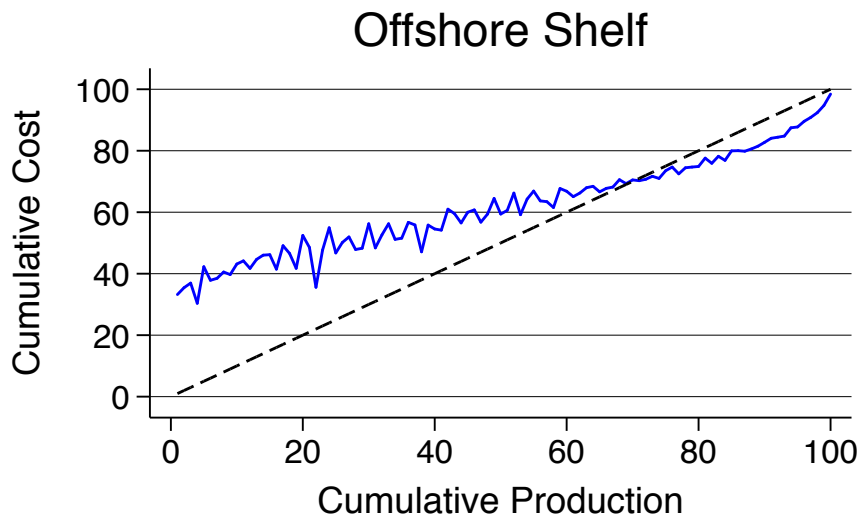
	Specification			
	(1)	(2)	(3)	(4)
Actual (A)	2829	2837	2670	2596
Counterfactual (C_1)	1917	1906	-	-
Counterfactual (C_2)	-	-	1825	2452
Total distortion (A - C_1)	912	931	-	-
Second-Best distortion (A - C_2)	-	-	845	144
Distortion due to OPEC	-	-	845	144
Upper bound	217	203	-	-
Lower bound	133	124	-	-

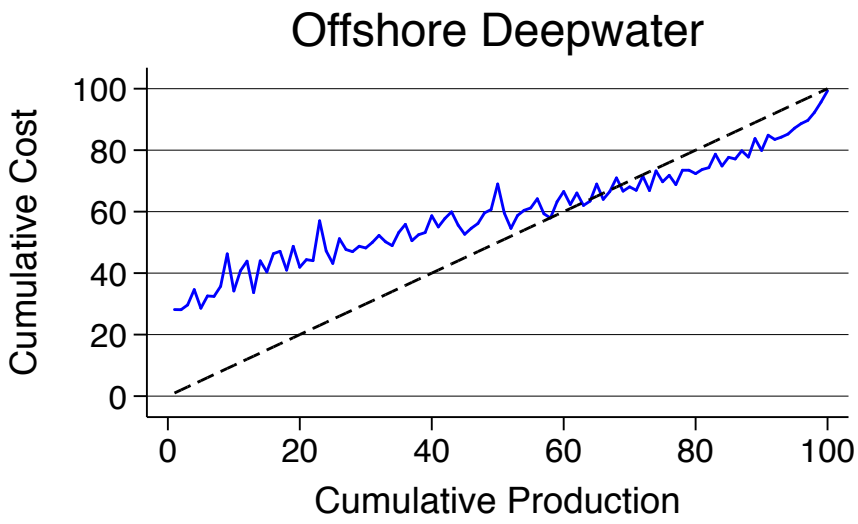
Conclusions

- 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.

Conclusions


Conventional Oil
Cumulative Cost
0
20
40
60
80
100
Cumulative Production


Offshore Shelf
Cumulative Cost
0
20
40
60
80
100
Cumulative Production


Offshore Deepwater
Cumulative Cost
0
20
40
60
80
100
Cumulative Production

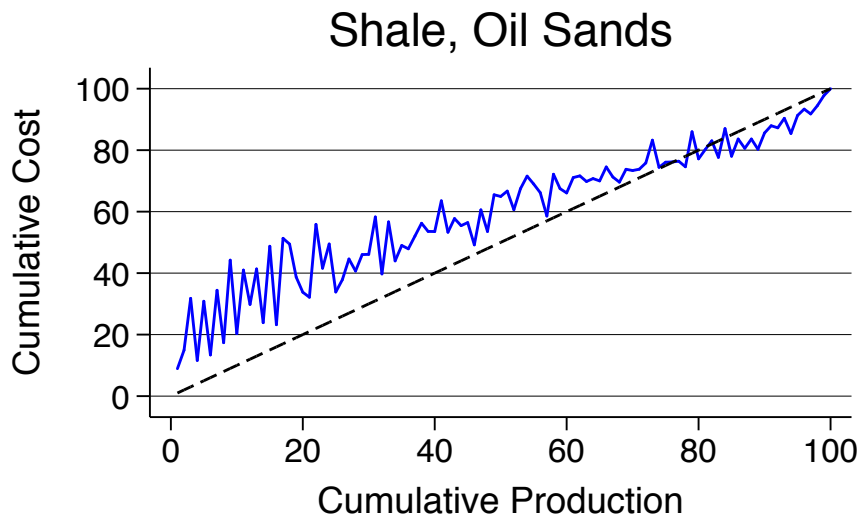
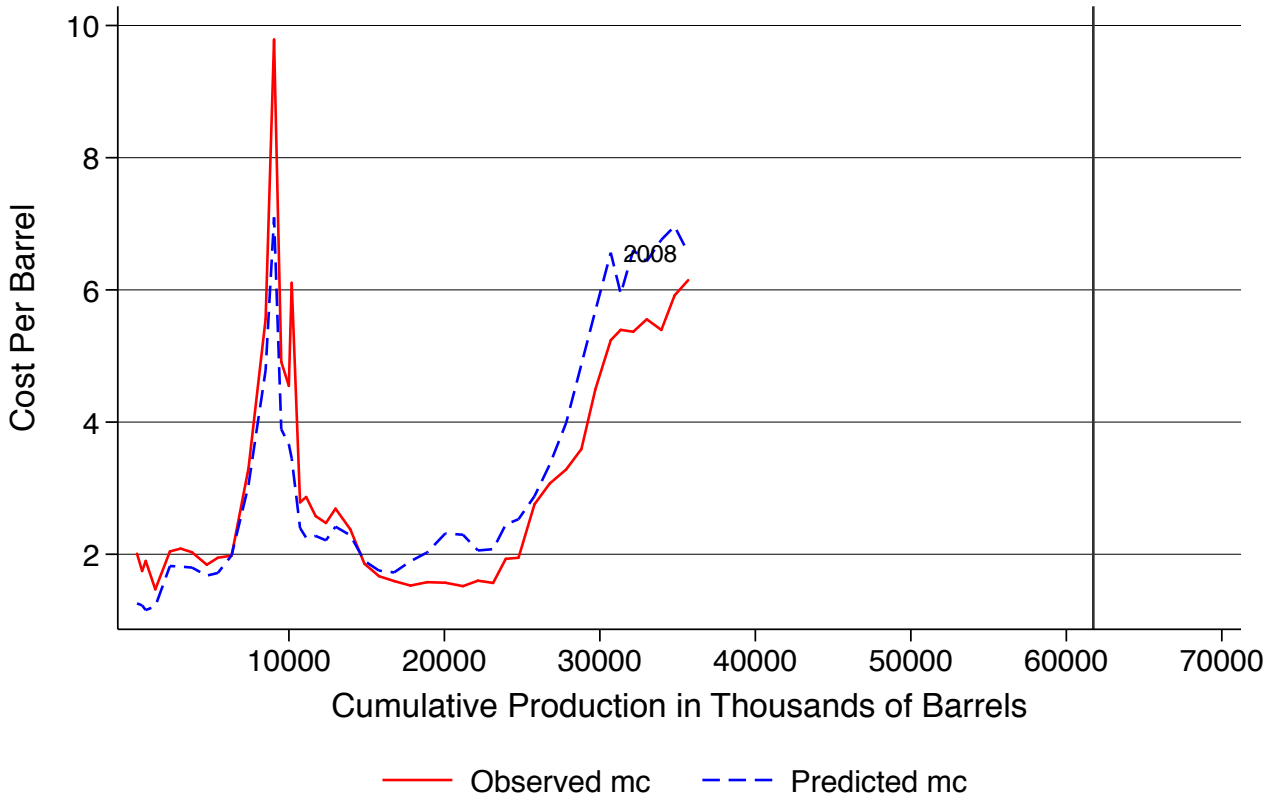

Shale, Oil Sands
Cumulative Cost
0
20
40
60
80
100
Cumulative Production

Figure: Observed and Predicted Marginal Cost
Ghawar Uthmaniyah (SA)



Notes: Observed and predicted marginal cost, using the cost specification in equation **??**, is plotted against cumulative production. The vertical line indicates the proven reserves, and we insert the production year 2008, the year with the highest oil price in the sample period 1970-2014.