The Environmental Benefits of Market Power In Oil

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Research Question

- How has OPEC's market power (and other distortions) offset the negative environmental externality from oil consumption from 1970 to 2021?
- Mesh existing IO approaches to measurement with emissions models and climate modelling
- Why care?
  - Market structure interacts with externalities (Buchannan, Lipsey & Lancaster, Stigler vs. Pigou)
  - Social impact of market power subject to open debate
  - Move in some jurisdictions to excuse potential market power abuses using climate-related justifications

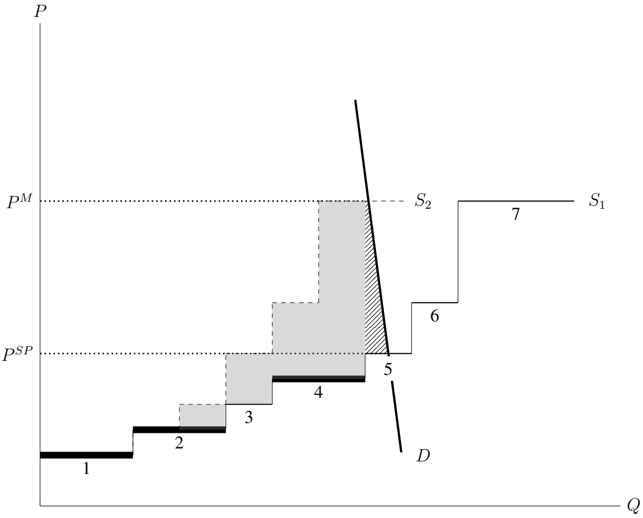
Punchline

- From 1970-2021, 67,738 $MtCO_2$ fewer emissions relative to competitive equilibrium benchmark.
  - Roughly 2 years worth of emissions.
  - Approx. 0.023°C reduction in temp = 17% of what remains to meet Paris commitments
- Valued at $250 per tCO_2, value of carbon saving is $4,073 billion
  - Total non-carbon welfare cost of OPEC market power is $1.2-2.5 billion in 2021 dollars
  - Total cost of all non-carbon distortions relative to competitive benchmark is $2.58 billion
- Nonetheless, market power from cartelization may not be an optimal policy objective...

Roadmap of the talk

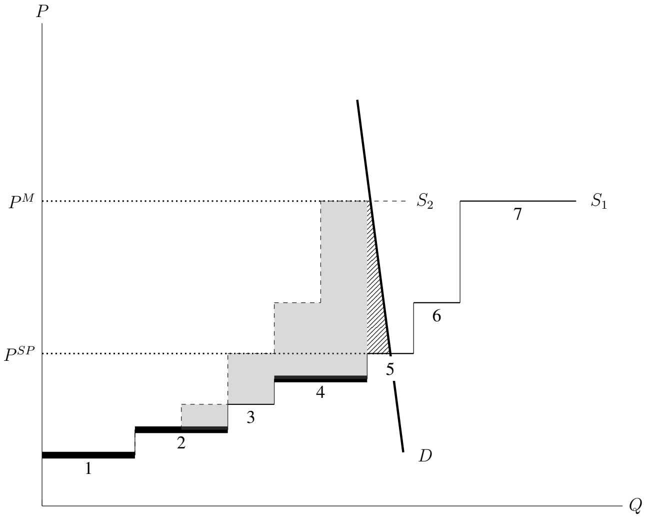
1. Economic Framework.
2. Oil industry: Quick intro
3. Measurement Inputs: Cost, Emissions and Demand
4. Results: Welfare & Emissions Analysis
5. Concluding remarks.

Welfare without CO_2



Fields 1, 2, and 4 are in the OPEC Cartel. Cartel does not supply 4 and only supplies half of 2.

Welfare without CO_2: Measurement



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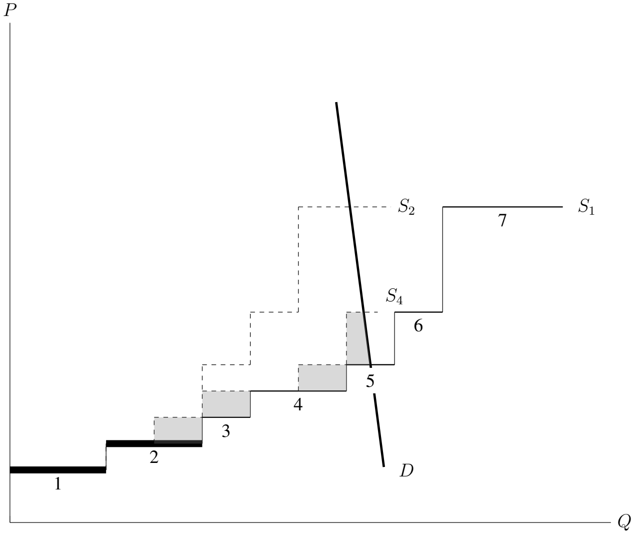
Framework under presence other distortions

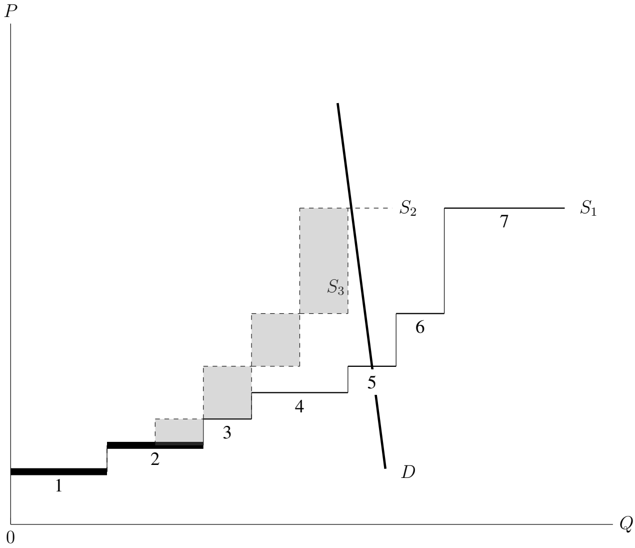
- Marginal approach: Given all other distortions, what is the *marginal* impact of market power?
- Inframarginal approach: *Absent* all other distortions, what is the impact of market power?
- Likely to matter in many applications of market power (corruption, criminal activity, technological constraints, information frictions, regulation, etc.)

Inframarginal approach



Fields 1 and 2 are in the OPEC Cartel. Due to ther distortions, 4 is not supplied. Cartel only supplies half of 2.

Marginal approach



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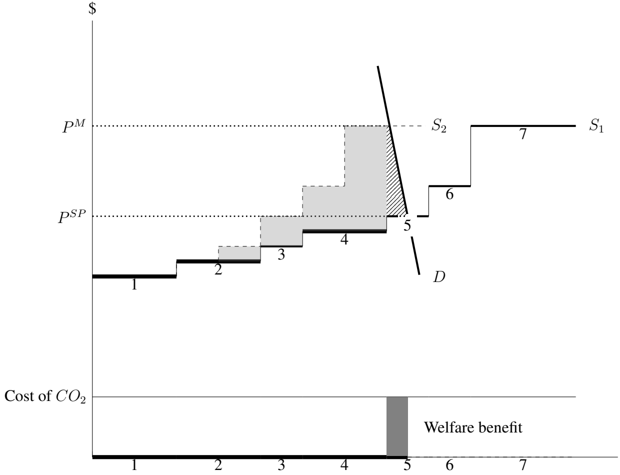
Welfare with CO_2



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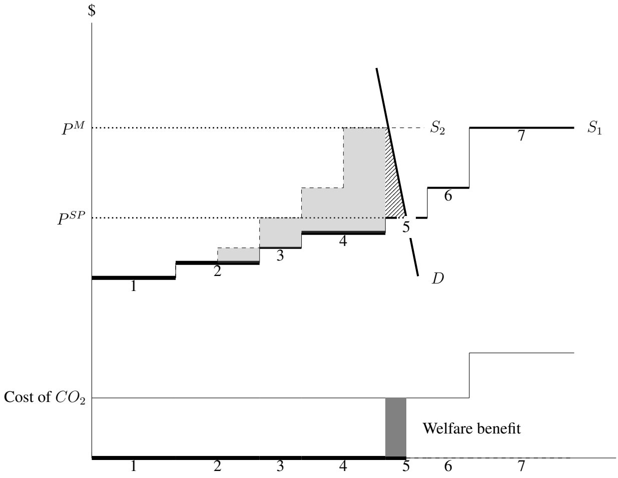

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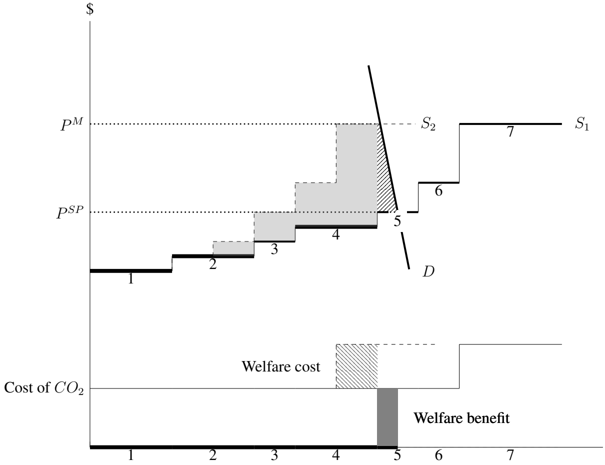
Welfare with CO_2



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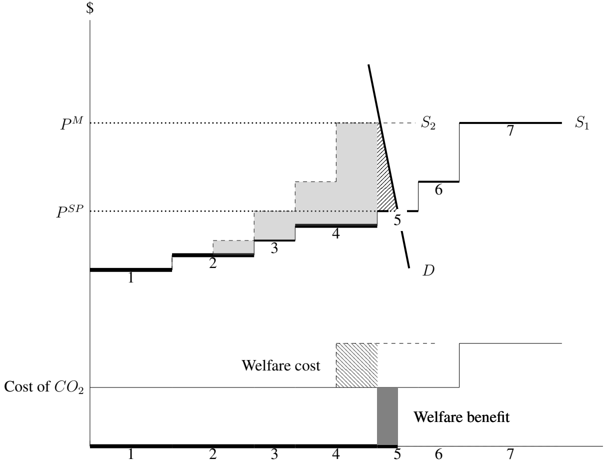
Welfare with CO_2: Measurement



Fields 1, 2, and 4 are in the OPEC Cartel. Cartel does not supply 4 and only supplies half of 2.

Dynamics

- The application will be the global upstream crude oil industry
- Taking this framework to that setting means taking these static intuitions and reworking them for a setting with dynamics (finite extraction problem)
- Account for dynamics (since oil is a finite resource)
  - Oil not used today is used in the future
  - Hotelling rents need to be accommodated

Dynamics ctd.

- Social Planner's problem (equiv: Competitive production path) is the allocation of barrels over time that maximizes gains from trade.

$$\mathcal{G}^{sp} = \max_{\{\mathcal{I}_t\}} \sum_{t=1}^{T} \delta^{t-1} \left(\int_0^{|\mathcal{I}_t|} D_t(x)dx - \sum_{i \in \mathcal{I}_t} c_{it} \right) \qquad (1)$$
$$\text{s.t.} \quad \mathcal{I}_t \subseteq \left\{ i | i \in \mathcal{I} \setminus \cup_{k=1}^{t-1} \mathcal{I}_k \right\}.$$

Notes:

  - $\mathcal{I}_t$ set of barrels in year t, i ranked barrels,
  - $D_t(.)$ demand, c_{it} cost of production,
  - $\mathcal{G}^s$ is NPV gains from trade,
  - constraint: cannot produce barrel produced in previous period

- *Sorting Algorithm:*
  lowest cost fields are extracted first in any competitive equilibrium – i.e. cost minimization ordering yields sequence of barrels (leverage assumption a) Leontief production function at field level and b) best estimate of a field's costs tomorrow are costs today)

Measurement Limitations: Dynamic Considerations

- RQ: How has OPEC's market power (and other distortions) offset the negative environmental externality from oil consumption from 1970 to 2021?
- Oil not used today is used in the future
- Where we leave things unresolved: All oil is likely consumed at some point. Implications depend on assumptions about CO_2 absorption. We leave this as an open question.

Required for analysis?

1. Cost curve
2. Map oil production at field level to CO_2 emissions
3. Map CO_2 to \$ value and temperature impact
4. Demand curve estimated with a global time series
5. A model of what a social planner would do
   - Theory guides computation of competitive market equilibrium
   - Theory allows measurement theoretical objects (welfare)
   - Avoid building a realistic model of how the cartel operates.

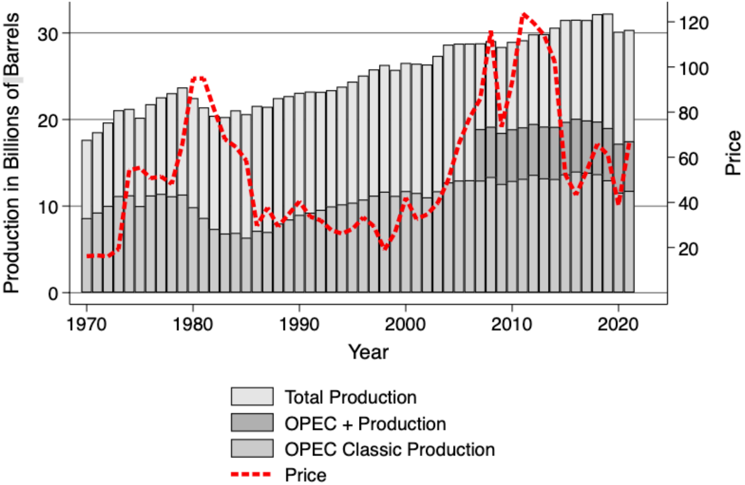
Global (crude) oil industry

- OPEC cartel,
- Data sources,
- Cost heterogeneity (PI) and large price swings (DWL).

The OPEC cartel

- OPEC "Classic" is Algeria, Angola, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE, and Venezuela formed in 1960.
- OPEC + formed in 2016 — informal coordination from 2008 onwards.

Prices and Production



Main Oil Producers

Table: Largest crude producers, % of global production 2021

OPEC +		Non-OPEC +	
Saudi Arabia	12.8%	United States	14.4%
Russia	12.5%	China	4.8%
UAE	4.3 %	Canada	2.8%
Iraq	3.9%	Norway	2.5%
Iran	3.8%	UK	1.0%
Koweit	3.0%		
Kazakstan	2.2%		
Qatar	2.1%		

- OPEC is an imperfect cartel.
- In 2021, 58% of production and 60% of world reserves in OPEC+

Data

- Cost analysis Asker, Collard-Wexler and De Loecker (2019) enhanced with data to the end of 2021.
- Rich Data on oil from Rystad Energy.
- 66K oil fields – 19K produce crude oil before 2021.
- Information on:
  1. production,
  2. (all line items of) costs,
  3. detailed info on reserves,
  4. technology,
  5. location.
  6. producing and non-producing fields.

Field-level cost

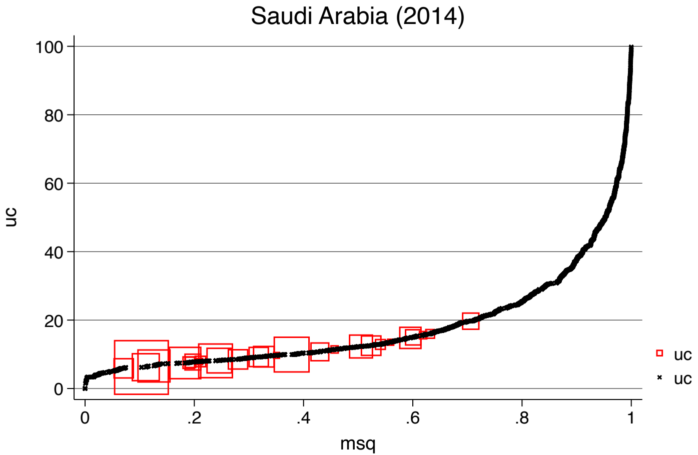
- Follow ACWDL (2019) and measure field-specific marginal (and average) cost:

$$c_{ft} = \frac{\sum_h \text{Expenditure}_{hft}}{q_{ft}}, \tag{2}$$

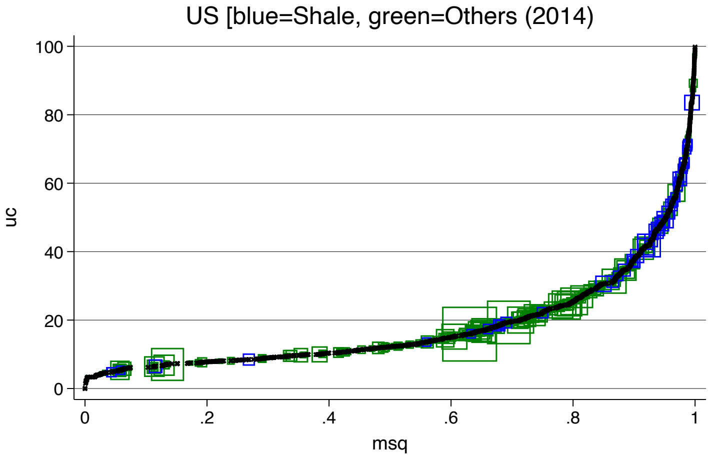
- Add in Rystad's estimates of break-even costs for never-producing fields.
- In estimating field costs so can move production inter-temporally, use this specification:

$$c_{ft} = c_f \, \mu_{st} \exp \varepsilon_{ft} \tag{3}$$

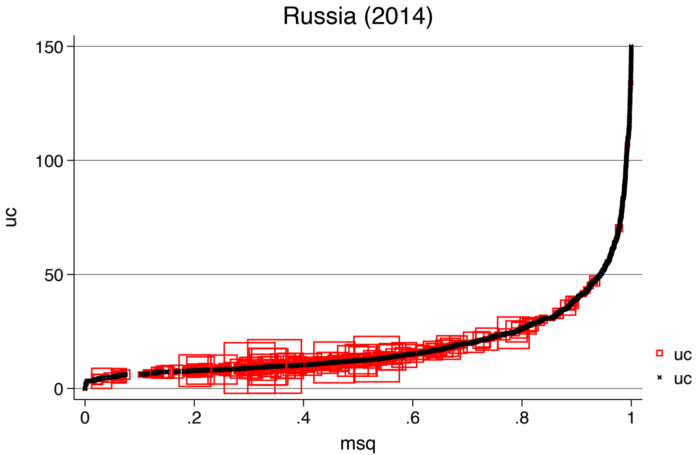
OPEC's position in the aggregate supply curve



US's position in the aggregate supply curve



Russia's position in the aggregate supply curve

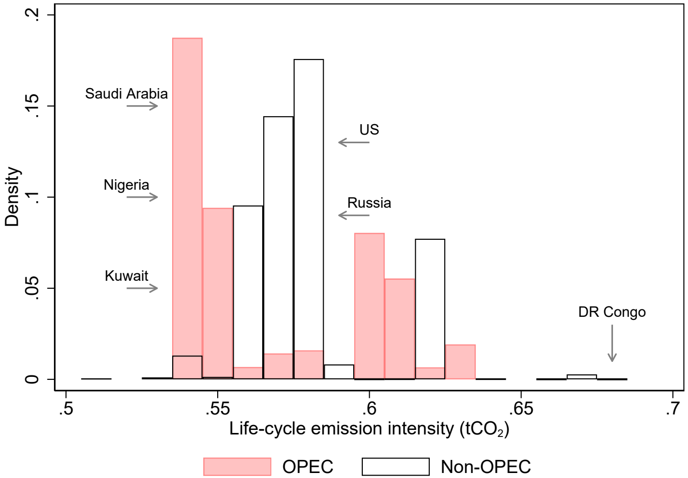


Emissions

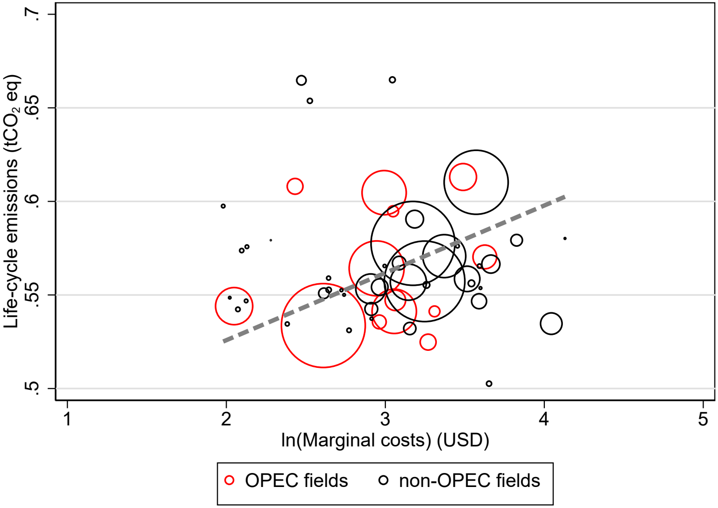
- Engineering estimates give emissions numbers
- tCO_2 per barrel a function of density, location, gas flaring, refinery technology, extraction method etc
  - Masnadi et al (2018) - upstream tCO_2 per barrel - about 11% of total
  - Jing et al (2020) - midstream tCO_2 per barrel - about 6% of total
  - Like Coulomb et al (2021) - downstream set at 0.464 tCO_2 per barrel - about 82% of total
- Country level data - checks out against country production mix characteristics
- Numbers are for 2015
- Value at social cost of carbon of $250 per tCO_2

Emissions: Heterogeneity

Figure 4: Life-cycle emissions intensity (tCO_2) across countries



Emissions: positively correlated with cost



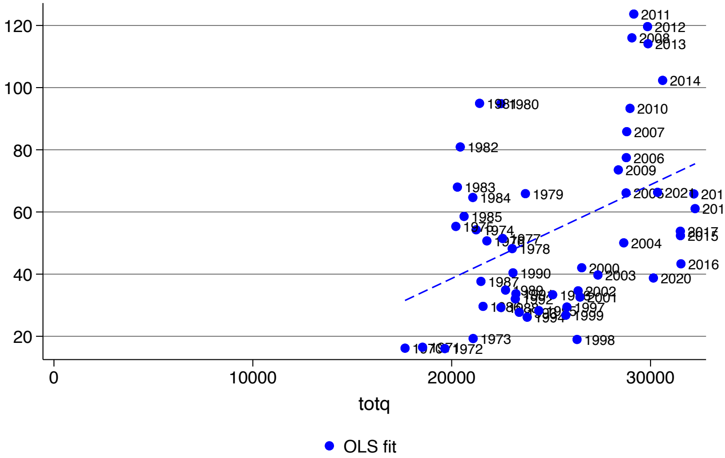
Inputs into simulations: Demand

Demand estimation using market-clearing (annual) prices and use costs to construct instrument.

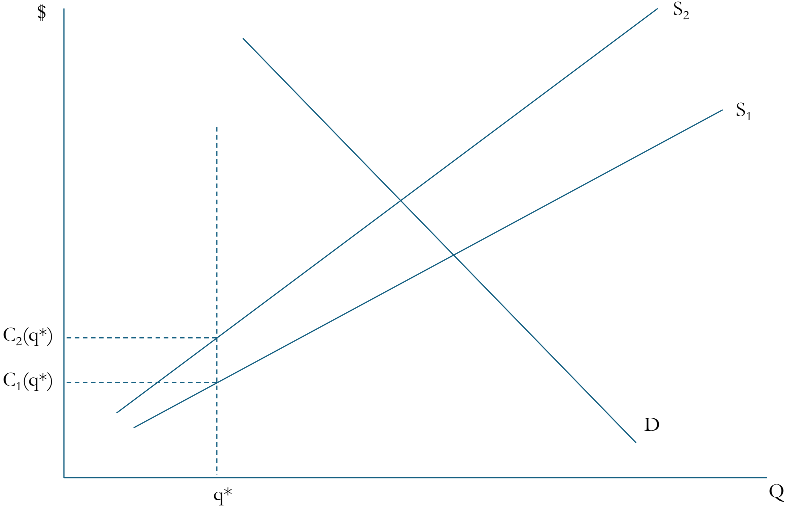
$$Q_t = \begin{cases} \alpha_p + \beta P_t + \gamma GDP_t + g(t) + \epsilon_t, & \text{if } P_t < 200 \\ 0 & \text{otherwise} \end{cases}$$

Estimating demand for oil

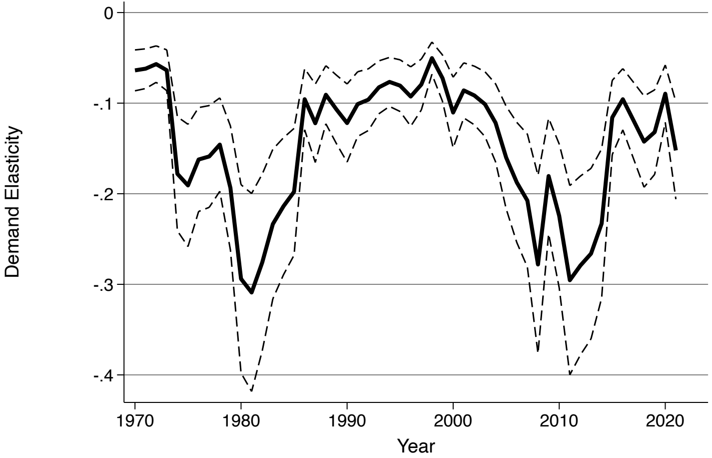
Identification trouble in a picture:



IV Strategy



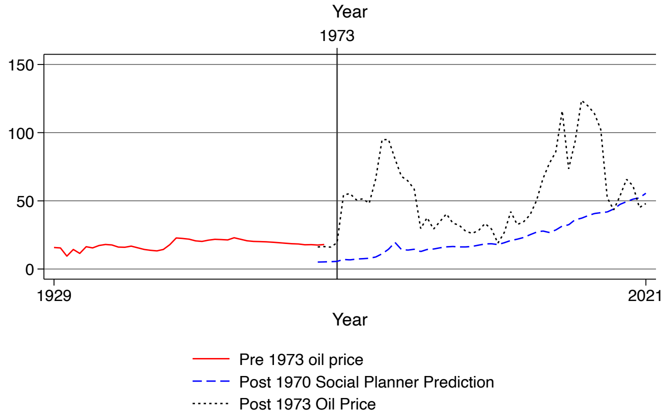
Price elasticities



Inputs into the Dynamic Structural Model

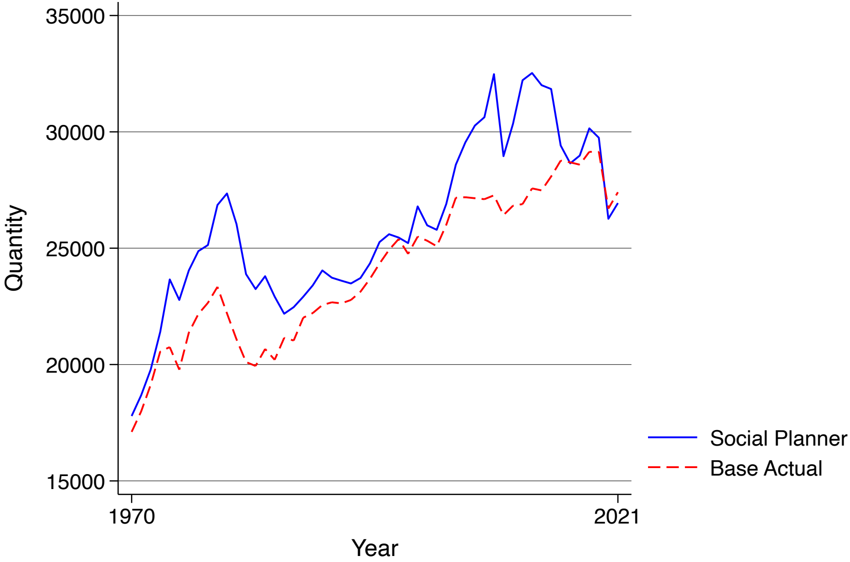
- Discount rate $\beta = 0.95$.
- Extraction rate max$\{$10 percent of reserves, max for field$\}$.
- Fields only extracted after discovery date and new discoveries as exogenous.
- Simulate out to 2100.
  - Demand growth set at 1.3 percent (geometric average over 1970-2021).
  - Forecasted production is optimal after 2021 (end of the data).
- Need to estimate counterfactual costs: what a field would have cost to extract in 1990 using data on costs in 2010.
- Need to estimate costs of fields that do not produce in the data: fields that will produce in 2032.

Dynamics: Price Paths

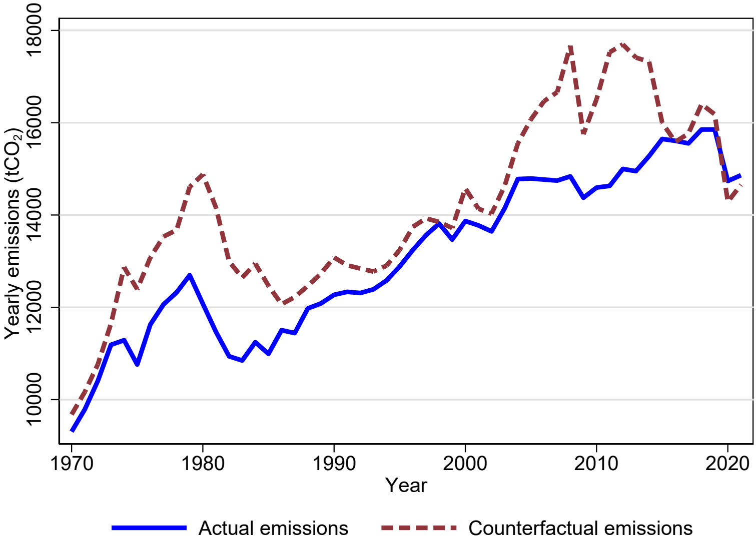


Comparing our social planner solution to the path of prices before 1973, the time when OPEC formed in 1960, starts to restrict output in a sizable way.

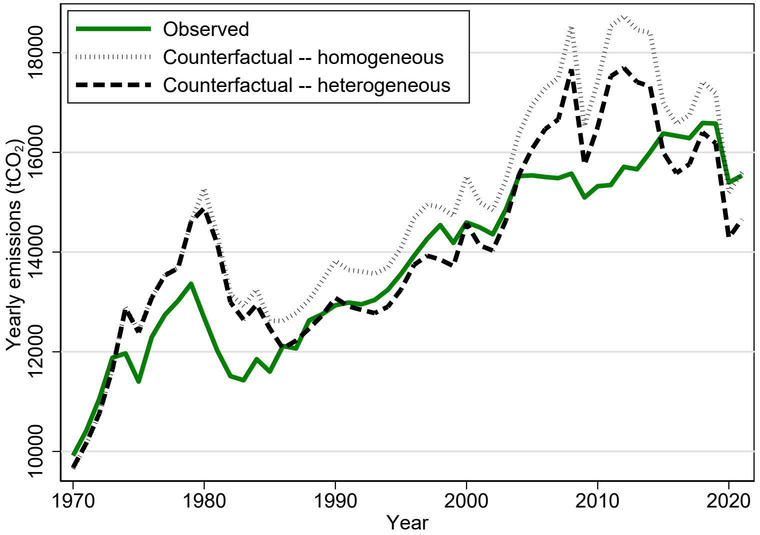
Dynamics: Output



Dynamics: Emissions, Homogenous at 0.544 tCO_2



Dynamics: Emissions, Heterogenous

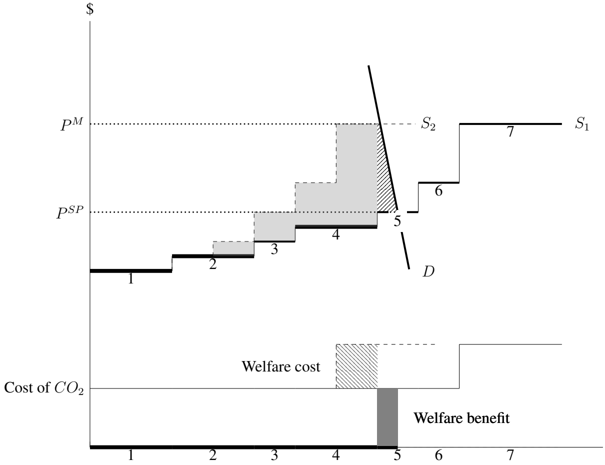


Welfare & Emissions Analysis: Results

Impact, 1970 - 2021, in billions of 2021 $

Non-CO_2 welfare objects	
Total Lost gains from trade	2,580
Market power (Marginal approach)	2,548
Market power (Inframarginal approach)	1,201
CO_2 welfare objects	
Emissions change	-4,073
Volume effect	-5,586
Composition effect	1,512

Welfare with CO_2



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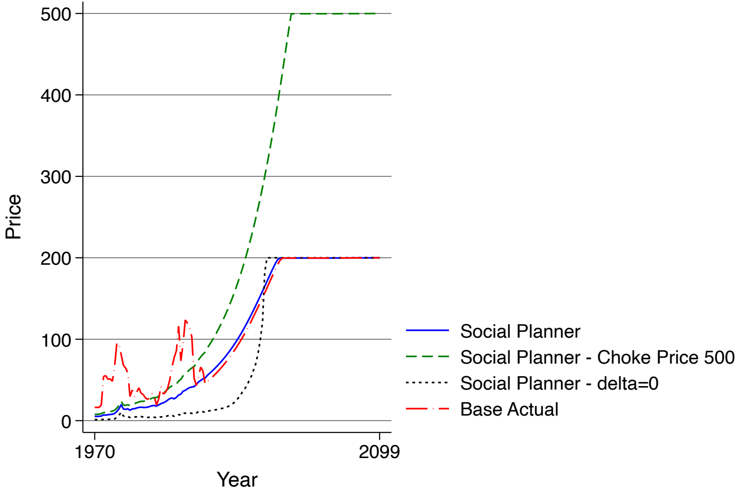
Interpreting the numbers and conclusion

1. Non CO_2 total welfare loss USD 2.58 Trillion(TWL) in the absence of frictions,
2. Benefit from CO_2 reductions about 2-4 times the cost of market power
3. Composition effect is equivalent to lower end of market power impact.
4. CO_2 reduction is equivalent to a 0.028-0.032°C reduction in temperature in 2021 relative to counterfactual
5. About 2 years of global emissions are avoided to date at a cost of roughly a bad US business cycle (rough cost via output gap of 2008 recession)

Dynamics



- After 2021, actual reverts to social planner.
- Parameterization of the hotelling problem matter: choke prices, discount rates, etc...

Distributional impact of OPEC

	Δ Welfare	Δ Profits	ΔCS
OPEC	-3.9	-5.0	1.1
Canada and USA	1.6	-2.2	3.8
EU and Japan	3.3	-0.7	4.0
ROW	1.6	-3.8	5.3

(All numbers in trillions of 2021 US dollars.)

Robustness: Demand and Cost Parameters

	LGFT	DWL	PI	LGFT Marginal	LGFT Inframarginal
Base	2,580	857	1,723	2,548	1,201
Choke 500	2,870	1,146	1,723	2,844	1,161
Choke 350	2,619	896	1,723	2,589	1,178
Demand upper	2,216	493	1,723	2,191	1,086
Demand lower	3,090	1,367	1,723	3,049	1,328
No extraction constraint	2,585	843	1,742	2,603	1,421