Introduction to Collusion and Cartels

John Asker*

May 21, 2018

1 Preliminaries: A general perspective on the economics of cartels

This section has the following objectives:

1. Give a framework for thinking about cartel research generally
2. Illustrate ways to attack these issues using examples of empirical research on cartels

2 Introduction: What are we talking about?

• Price fixing
• Bid rigging
• Market division schemes and other forms of “non-price” collusion
• Group boycotts
• Coordinated refusal to deal
• Joint ventures
• Information sharing among competitors

3 Section 1 cases: Anticompetitive Agreements

This is where our primary focus lies. Recall that section 1 reads:

*Email: johnasker@econ.ucla.edu, www.johnasker.com
Sec. 1. Every contract, combination in the form of trust or otherwise, or conspiracy, in restraint of trade or commerce among the several States, or with foreign nations, is hereby declared to be illegal. Every person who shall make any such contract or engage in any such combination or conspiracy, shall be deemed guilty of a misdemeanor, and, on conviction thereof, shall be punished by fine not exceeding five thousand dollars, or by imprisonment not exceeding one year, or by both said punishments, at the discretion of the court.

Basically you need i) capacity to agree, ii) an agreement, iii) a restraint of trade, and iv) unreasonableness. Note that without unreasonableness, pretty much every commercial contract would have trouble.

There is an expansive set of American law that unpacks all of this stuff. The main point is that harm to competition is the basic key to unreasonableness. Further, a lot more than collusion is covered by this section. However, collusion is often treated as a per se offense, which means that very very fact of it is enough to gets past the unreasonableness standard.
• Monopolization:
  – Predatory conduct
  – Refusal to deal
  – Other exclusionary conduct

• Anticompetitive (horizontal) Agreements:
  – Price fixing
  – Bid rigging
  – Market division schemes and other forms of “non-price” collusion
  – Group boycotts
  – Coordinated refusal to deal
  – Joint ventures
  – Information sharing among competitors

• Anticompetitive Vertical Restraints:
  – Resale Price Maintenance
  – Exclusive Dealing /Exclusive Distributorships
  – Exclusive sales territories
  – Tying / Full Line Forcing
  – Various quantity limit provisions etc

• Mergers and Aquisitions:
  – Horizontal
  – Vertical
  – Conglomerate
  – Large asset aquisitions e.g. Nortel Patent Portfolio

• Price Discrimination
  – Robinson Patnam Act largely about protecting small business in B2B transactions

• Unfair/Deceptive Methods of Competition (§5 of FTC Act)
lower but more individuals and corporations were charged per prosecution; that is, per capita fines were lower. During the later years, the number of individuals and corporations charged per prosecution were lower, but fines were much higher. This indicates that the criminal enforcement strategy shifted to one of sending a clear deterrence signal through higher monetary fines.

Figure 1. Total (a) criminal and (b) antitrust cases filed, 1948–2003. (c) Ratio of criminal to total cases.
4 Structuring the economics of collusion

I find the introduction to the following paper from McAfee and Macmillan to be helpful in this regard.
Bidding Rings

By R. Preston McAfee and John McMillan*

We characterize coordinated bidding strategies in two cases: a weak cartel, in which the bidders cannot make side-payments; and a strong cartel, in which the cartel members can exclude new entrants and can make transfer payments. The weak cartel can do no better than have its members submit identical bids. The strong cartel in effect reauctions the good among the cartel members. (JEL D44, D82, L41)

A successful cartel must overcome at least four obstacles. First, the conspirators must devise some mechanism for dividing the spoils. Each cartel member has an incentive to argue for a bigger share. Second, an agreement is worthless without some way of enforcing it. Since contracts to fix prices cannot usually be written, any collusive agreement must be designed to be self-enforcing. Third, collusion contains the seeds of its own destruction. The high profits earned in a successfully colluding industry attract new firms into the industry; the competition from those new entrants then tends to destroy the collusive arrangements. Fourth, the victims of the cartel, on the other side of the market, may take actions to destabilize it. The first of these problems is empirically at least as important as the other three: for example, in a sample of international cartels that were temporarily successful but then broke down, almost half were destroyed by internal squabbling over how to share the profits (Paul Eckbo, 1976 Ch. 3). Most of the U.S. Department of Justice’s bid-rigging convictions begin when one of the cartel members, dissatisfied with his share of the spoils, turns in his coconspirators.

The main subject of this paper is how cartels overcome the division-of-the-spoils difficulties, in the specific context of bidding at auctions.¹ The colluding bidders must overcome an adverse-selection problem: they do not know how much each of their fellow cartel members is willing to pay for the item being sold. We shall derive the optimal mechanism for the cartel to use to decide who receives the item and how the proceeds are distributed. Our model will also have something to say about two of the other cartel problems listed above: entry deterrence and active seller responses. We shall, however, have nothing to add to what has already been said about cartel enforcement (see e.g., George Stigler, 1964; Dilip Abreu et al., 1986).

We examine primarily all-inclusive bidder cartels at sealed-bid first-price auctions,² except in Section VI, where we offer a partial analysis for bidder cartels that contain

*Department of Economics, University of Texas, Austin, TX 78712-1173, and Graduate School of International Relations and Pacific Studies, University of California-San Diego, La Jolla, CA 92093-0519, respectively. We thank Louis-André Gérard-Varet, Charles Holt, Ignatius Horstmann, Chantale LaCasse, Robert Marshall, Joel Sobel, and three referees for comments. McAfee’s research was begun at the U.S. Department of Justice. McMillan thanks the National Science Foundation for research support under grant no. SES-8721124.

¹Biddings conspiracies are prevalent enough to have added some exotic locutions to the English language. Cartels are variously called “rings,” “pies,” and “kippers.” A “schlepper” is an insincere bidder attracted solely by the cartel’s profits, and a “shill” is a phony bidder used by the auctioneer to drive up the price. A “knockout” is a private auction held by the cartel to determine which member gets the item and how much he pays the other members.

That is, a successful cartel must overcome at least four obstacles.

- First, the conspirators must devise some mechanism for dividing the spoils. Each cartel member has an incentive to argue for a bigger share.
- Second, an agreement is worthless without some way of enforcing it. Since contracts to fix prices cannot usually be written, any collusive agreement must be designed to be self enforcing.
- Third, collusion contains the seeds of its own destruction. The high profits earned in a successfully colluding industry attract new firms into the industry; the competition from those new entrants tends to destroy the collusive arrangements.
- Fourth, the victims of the cartel, on the other side of the market may take actions to destabilize it.

A large body of theory, mostly in repeated games and mechanism design is directed at understanding points 1,2 and 4. See, for instance: McAfee and McMillian; Graham, Marshall and Richard; Harrington and Skrzypacz. I think point 3 is wildly understudied.

On the empirical side I tend to think of papers as tending to be cover one or more of the following topics

1. How to detect a cartel
2. Assessing market impact
3. Evaluating theory
4. Descriptive (relating to issues that are poorly understood in theory or empirics)

This means that you tend to be able to put an empirical paper on cartels in a 4x4 square. Sometimes things fall in the gaps, but it’s a useful way to place papers in the literature and see open issues. Of the papers we have seen so far, let’s try to understand where they lie.
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5 Cartel Examples

- Price fixing
- Bid rigging
- Market division schemes and other forms of “non-price” collusion
- Group boycotts
- Coordinated refusal to deal
- Joint ventures
- Information sharing among competitors

For a fun insight into cartel mechanics type “youtube lysine cartel 6” into google and look to the explanation of what the video is at
References

Bork, Robert (1978), *The Antitrust Paradox*,


Lectures on Collusion and Bidding Rings:

A Study of the Internal Organization of a Bidding Cartel


The reasons for looking at this are:

a) Example of empirical cartel research

b) Illustration of how auction-related econometrics can be leveraged for an applied question.
## Place in literature

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Introduction: Collusion in an English Auction

$\text{Value of Bidder 1}$

$\text{Value of Bidder 2}$

$\text{Value of Bidder 3}$

$\text{Value of Bidder 4}$
Introduction: Collusion in an English Auction

Price = 8 if everyone competes

Value of Bidder 1: 10
Value of Bidder 2: 8
Value of Bidder 3: 5
Value of Bidder 4: 3
Introduction: Collusion in an English Auction

Price = 5 if Bidders 1 and 2 collude.
Introduction: Collusion in an English Auction

Price = 8 if Bidders 1 and 3 collude

Value of Bidder 1: 10
Value of Bidder 2: 8
Value of Bidder 3: 5
Value of Bidder 4: 3
Introduction

• Research Question:
  • “How do bidding rings work in practice?”
  • “How might rings affect market outcomes?”

• To do this I analyze the activity of ring of 11 stamp dealers who colluded in North American stamp auctions for around 20 years

• Why is this interesting?
  • Regulatory reasons: Price Fixing and Bid Rigging are Illegal
  • There is very little evidence on how cartels organize themselves
  • We know very little about the magnitude of the impact of cartel design on revenues and efficiency
Ring Organization

Ring Exists:
- 11 Stamp Dealers
- Subset of all Bidders
- Each ring member decides whether interested in the object for sale

Knockout Auction:
- First Price Sealed Bid
- Decides: who gets the stamps if the ring wins
- At what price they stop
- The side payments

Target Auction:
- English – Open Outcry Ascending Bid
- Winner Pays Own Bid
- Cartel bids up to the winning knockout bid.
Consider the following data:

<table>
<thead>
<tr>
<th>Data ID</th>
<th>Bidder</th>
<th>House</th>
<th>Date</th>
<th>Lot #</th>
<th>Sidepayments</th>
<th>Rank</th>
<th>Knockout Bid</th>
<th>Target Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>989</td>
<td>K</td>
<td>hrh</td>
<td>5-Dec-1996</td>
<td>954</td>
<td>-250</td>
<td>1</td>
<td>3400</td>
<td>1350</td>
</tr>
<tr>
<td>990</td>
<td>C</td>
<td>hrh</td>
<td>5-Dec-1996</td>
<td>954</td>
<td>237.5</td>
<td>2</td>
<td>1850</td>
<td>1350</td>
</tr>
<tr>
<td>991</td>
<td>J</td>
<td>hrh</td>
<td>5-Dec-1996</td>
<td>954</td>
<td>12.5</td>
<td>3</td>
<td>1400</td>
<td>1350</td>
</tr>
<tr>
<td>992</td>
<td>I</td>
<td>hrh</td>
<td>5-Dec-1996</td>
<td>954</td>
<td>0</td>
<td>4</td>
<td>1200</td>
<td>1350</td>
</tr>
<tr>
<td>993</td>
<td>D</td>
<td>hrh</td>
<td>5-Dec-1996</td>
<td>954</td>
<td>0</td>
<td>5</td>
<td>725</td>
<td>1350</td>
</tr>
</tbody>
</table>

The catalog description is:

ITALY AND AREA

954 星日 19th and 20th Century, coll. of many hundred diff., plus hundreds of dupl., in 2 Minkus albums and loose pages in carton, l.h. to unused and used, mostly Italy with a wide range of issues incl. many compl. sets, some modern n.h., blks and corner blks, Airs, back-of-book, Aegean Is., San Marino, etc., mixed condition to very fine. Est. Cash Value $750-1,000

Bidding data collected and generously provided by Antitrust Division of NY State AG’s Department.
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Computing side payments:

D & I get nothing: 1350 > 1200 > 725

J does get a sidepayment:

Take the difference between bid and target price:

$$1400 - 1350 = 50$$

½ of this goes to the winner (K)

½ gets split between C & J

Hence, J’s sidepayment is $12.5
Approach:
• IPV style model
• 2 types of bidder: strong and weak
• Focus on 2 bidder knockouts (tractable + identified + lots of data)

Bid = argmax: (Value of object - Expected payment in target if win) x (Prob of winning)

- (Expected payment to loser if win) x (Prob of winning and having to make a payment)

+ (Expected payment from winner if lose) x (Prob of losing knockout) x (Prob of beating the price in target)
Approach:
• IPV style model
• 2 types of bidder: strong and weak
• Focus on 2 bidder knockouts (tractable + identified + lots of data)

First Order Condition is:
\[ v_{ik} = b_{ik} - \frac{1}{2} \left[ \frac{F_r(b_{ik})(1 - G_{-i}(b_{ik}))}{f_r(b_{ik})G_{-i}(b_{ik}) + F_r(b_{ik})g_{-i}(b_{ik})} \right] \]

This provides a mapping from bids to values, such that \( v(b) \) is a function: for each \( b \) there is a unique \( v \)
Data

• Complete record of ring’s activity from July 1996 – June 1997
• Also depositions from the taxi driver and one of the ring members
• 1967 target auctions.

• Data Summary:

Table 2: Bidding by number of bidders in the knockout

<table>
<thead>
<tr>
<th># of Bidders</th>
<th>Target Auction (Winning Bid) Mean</th>
<th>Target Auction (Winning Bid) Standard Dev.</th>
<th>Knockout Auction (Median Bid) Mean</th>
<th>Knockout Auction (Median Bid) Standard Dev.</th>
<th>% Of lots won by ring</th>
<th>Total Number of lots</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>733</td>
<td>1262</td>
<td>616</td>
<td>1134</td>
<td>19%</td>
<td>623</td>
</tr>
<tr>
<td>2</td>
<td>1314</td>
<td>2016</td>
<td>1066</td>
<td>2048</td>
<td>36%</td>
<td>367</td>
</tr>
<tr>
<td>3</td>
<td>2014</td>
<td>3246</td>
<td>1750</td>
<td>3029</td>
<td>48%</td>
<td>260</td>
</tr>
<tr>
<td>4</td>
<td>2217</td>
<td>3492</td>
<td>2293</td>
<td>4082</td>
<td>69%</td>
<td>196</td>
</tr>
<tr>
<td>5</td>
<td>2249</td>
<td>3419</td>
<td>2092</td>
<td>3322</td>
<td>68%</td>
<td>144</td>
</tr>
<tr>
<td>6</td>
<td>2098</td>
<td>2628</td>
<td>2163</td>
<td>3014</td>
<td>74%</td>
<td>91</td>
</tr>
<tr>
<td>7</td>
<td>2979</td>
<td>3425</td>
<td>3655</td>
<td>4116</td>
<td>86%</td>
<td>74</td>
</tr>
<tr>
<td>8</td>
<td>4790</td>
<td>4904</td>
<td>6233</td>
<td>7726</td>
<td>96%</td>
<td>26</td>
</tr>
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</table>

Notes: Does not include the Harmer-Schau auctions. All subsequent analysis also excludes these auctions.
‘Weaker’ Bidders

Net Payments From the Ring, By Member

-80000 -70000 -60000 -50000 -40000 -30000 -20000 -10000 0 10000 20000 30000

All Auctions Auditions with target price ≤$10,000
Reduced Form: Summary

- Ring participants are heterogeneous

- ‘Weaker’ bidders are a problem
Objectives:

A. Measure damages:
   - To the seller
   - To the other bidders who are not members of the ring

B. Measure the market inefficiency introduced by this knockout design

C. Measure the returns to the cartel from colluding
   - It all amounts to estimating a version of a markup
Structural Analysis: Estimation (Basic Idea)

Observables: $b_{ik}$, other Bids in auction k, Bids in other auctions

Nonparametric estimation (kernels) give densities

Empirical CDF gives distributions

2 Bidders in Knockout

IPV Setting

$$v_{ik} = b_{ik} - \frac{1}{2} \left[ \frac{F_r(b_{ik})(1-G_{-i}(b_{ik}))}{f_r(b_{ik})G_{-i}(b_{ik}) + F_r(b_{ik})g_{-i}(b_{ik})} \right]$$

Compute valuation, bootstrap standard errors
Structural Analysis: Estimation (Issues)

1. Getting the distribution of the winning target price (highest non-ring valuation)

   There is a selection problem in the data which I explicitly model.

2. Observed auction level heterogeneity

   First stage OLS regression approach

3. Unobserved auction level heterogeneity

   Adopt the deconvolution technique first adapted to first price auctions to deal with unobserved heterogeneity by Krasnokutskaya (2004).

4. Non-monotonicity of bid function

   Need to make sure smoothing parameters do not let this happen
Steps in Estimation

Step 1: Regress Bids on observed auction characteristics

Step 2: Work with residual from step 1
Step 2a: Do the deconvolution

Step 3: Work with a sample drawn from the idiosyncratic bid distribution
Step 3a: Selection correction on distribution of highest non-ring bid
Step 3b: Adapted GPV procedure

Step 4: Add the common element from the deconvolution back in

Step 5: Add the observed auction characteristics back in

Step 6: Counterfactual simulations
Bid Function: Sincere Bidder, Common Component of Valuation = 450, 70% chance of facing another sincere bidder, 30% chance of facing an insincere bidder in the knockout.
Assessing Damages

• An estimated model allows us to run the counterfactual experiment: What would have happened if the cartel did not exist?

• Note that the estimated model allows standard errors to be computed and thus we can engage in statistical inference (i.e. hypothesis testing etc).

• What we learn:
  
  • Sellers suffer to the tune of $30 each time the ring wins
  • But when the ring loses they get somewhere between $0 and $20 more
  • Competing bidders get hurt by about $10 when the ring wins and $0 to $20 when the ring loses
  • The ring made about $25 each time they won
  • Economic efficiency was not affected in any meaningful way, unless participation was detered by the ring.
(Mis)Allocation, Market Power, and Global Oil Extraction

John Asker
UCLA and NBER

Allan Collard-Wexler
Duke and NBER

Jan De Loecker
KU Leuven, NBER and CEPR

July 1, 2018
Jerusalem
Motivation

- Research Question: *Impact of market power (i.e. OPEC) 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: comparatively little focus on resource misallocation resulting from market power (esp. from cartels).
  - Revisit 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

\[ Q = q_1 + q_2 \]

Asker, Collard-Wexler, De Loecker
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*. 
Main Findings

- Costs of oil production are 10 percent higher due to the OPEC cartel: a 163 billion dollar welfare loss over a 45 year period.
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Map of Talk

- Oil and OPEC
- Data
- Model
- Empirical Analysis
- Conclusion
Geology and location have a big impact on costs of extraction.

Exogenous cost variation across production units unrelated to management skill:
- Technology: onshore, offshore, shale, etc.
- Location (geology): bedrock structure, climate, etc.

What productivity (equiv. cost) is a little clearer here than in most markets.

Examples:
OPEC is Algeria, Angola, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE, and Venezuela.

OPEC is an imperfect cartel

In 2014, 50% of world reserves in OPEC, and the rate of extraction in OPEC was half as fast as in the rest of the world.
Map of Talk

- Oil and OPEC
- Data
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- Conclusion
Cost Changes over time: Saudi Arabia

black: 95%, grey: 99% and circle: max.
Cost Changes over time: United States
Map of Talk

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

\[ Q = q_1 + q_2 \]
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.
Characterization of Equilibrium

Assumptions:
- Homogenous product market
- Common discount factor $\delta$
- Constant marginal cost $= c_f \mu_{st}$ (equiv. Leontief production function)
- Martingale Assumption on expectation of $\mu$:

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

Implication:

*Sorting Algorithm*: lowest cost fields are extracted first in any competitive equilibrium.
Map of Talk

- Oil and OPEC
- Data
- Model
- **Empirical Analysis**
- Conclusion
Use the sorting algorithm to compute counterfactual paths for the industry — the competitive path.
Inputs into the Dynamic Structural Model

- Discount rate $\beta = 0.95$.
- Physical limits on how much oil can be extracted at once. We cap the extraction rate at $\max\{10$ percent of reserves, max for field\}.
- 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 1970-2014, 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:

\[ c_{fts} = c_f \mu_{st} \exp(\epsilon_{f,t,s}) \] (1)

1. First estimate \( \mu_{st} \): Compute the average unit cost of production by year \( t \) and technology \( s \):

\[ \ln \hat{\mu}_{st} = \sum_{f \in s} \kappa_{fts} \ln c_{f,t,s}, \] (2)

where \( \kappa_{fts} \) is the quantity weight of a field in a given year’s total output,

\[ \kappa_{fts} = \frac{q_{ft}}{\sum_{f \in s,t} q_{ft}}. \]

2. Next: Recover an estimate of field-specific marginal cost shifter \( c_f \), allowing for measurement error, using the following regression:

\[ (\ln c_{fts} - \ln \hat{\mu}_{st}) = \ln c_f + \epsilon_{f,t,s} \] (3)
Note: Static distortions for each year are presented in 2014 dollars (left vertical axis), with the total height of each bar representing the difference between the actual cost of production and the optimal cost of production (the total distortion). Each bar is decomposed into the following distortions (from bottom to top): Within country (non-OPEC); Within country (OPEC); Across country (Within non-OPEC); Across country (within OPEC, in grey); Between OPEC and non-OPEC (in black). Definitions of distortions decompositions mirror those in table 6, although only applying to the individual year of interest. The oil price is shown using the black line dollars corresponding to the right vertical axis.
Table 6: Dynamic counterfactual results
(NPV of costs in billions of 2014 dollars)

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<tbody>
<tr>
<td>Actual (A)</td>
<td>2184 (125)</td>
<td>2499 (130)</td>
</tr>
<tr>
<td>Counterfactual (C)</td>
<td>1268 (76)</td>
<td>1756 (79)</td>
</tr>
<tr>
<td>Total distortion (A - C)</td>
<td>916 (124)</td>
<td>744 (112)</td>
</tr>
</tbody>
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Decomposition of total distortion

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Within country (non-OPEC)</td>
<td>329 (80)</td>
<td>284 (41)</td>
</tr>
<tr>
<td>Within country (OPEC)</td>
<td>192 (46)</td>
<td>157 (72)</td>
</tr>
<tr>
<td>Across country (within non-OPEC)</td>
<td>163 (18)</td>
<td>139 (17)</td>
</tr>
<tr>
<td>Across country (within OPEC) (X)</td>
<td>85 (22)</td>
<td>58 (21)</td>
</tr>
<tr>
<td>Between OPEC and non-OPEC (Y)</td>
<td>148 (29)</td>
<td>105 (25)</td>
</tr>
</tbody>
</table>

Production distortion due to OPEC market power

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<tbody>
<tr>
<td>Upper bound (X+Y)</td>
<td>233 (42)</td>
<td>163 (38)</td>
</tr>
<tr>
<td>Lower bound (Y only)</td>
<td>148 (29)</td>
<td>105 (25)</td>
</tr>
</tbody>
</table>

Notes: The NPV of costs from 1970 to 2014, and to 2100 (exhaustion of all fields), are reported in billions of 2014 dollars (assuming a 5 percent discount rate). Results are for the baseline specification: a field extraction rate of 10 percent of reserves is imposed in the counterfactual, the p50 measures of reserves are used where needed and a demand growth rate of 1.3 percent per year after 2014 is assumed. The Actual path is that observed in the data. The Counterfactual path is that computed using the unconstrained sorting algorithm. The within country (non-OPEC) decomposition takes the path from the sorting algorithm in which all non-OPEC countries are constrained to produce their actual production. OPEC fields produce as in the data. The reported number is A - [the NPV of the costs of this path] = D1. The within country (OPEC) decomposition is the mirror of this for OPEC countries ( = D2). The across country (within non-OPEC) decomposition takes the path from the sorting algorithm in which non-OPEC production is constrained to match the observed amount. OPEC fields produce as in the data. The reported number is A - D1 - [the NPV of the costs of this path] = E1. The across country (within OPEC) decomposition is the mirror of this for OPEC countries ( = E2). The Between OPEC and non-OPEC decomposition takes the path from the unconstrained sorting algorithm. The reported number is A - D1 - D2 - E1 - E2 - C = F1. Bootstrapped standard errors in parenthesis using 50 bootstrap replications.
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.