Measuring the Incentive to Collude

- Collusion (cooperation with competitors)
  - Main application of repeated game theory
  - Key issue in antitrust and IO
- Measuring the incentives of colluding firms
  - First step to understand cartels in reality
  - …and to inform antitrust policy
- Mission impossible…
  - Theory says anything can be equilibrium (Folk Theorem).
    - Theoretical explanation and prediction require detailed information on firms’ payoffs, strategies, and beliefs.
  - But data don’t exist because…
    - explicit collusion (= cartel) is per se illegal, and
    - tacit collusion is, well, tacit.
  ⇒ End of the theorist-empiricist cooperation?
### The Vitamin Cartels, 1990–1999

One of the biggest antitrust cases ever

<table>
<thead>
<tr>
<th>Rank</th>
<th>Product</th>
<th>Firm</th>
<th>Year</th>
<th>Country</th>
<th>Geographic scope</th>
<th>Fine ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vitamins</td>
<td>Roche</td>
<td>1999</td>
<td>Switzerland</td>
<td>International</td>
<td>500</td>
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<tr>
<td>2</td>
<td>LCD panels</td>
<td>AU Optronics</td>
<td>2012</td>
<td>Taiwan</td>
<td>International</td>
<td>500</td>
</tr>
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<td>3</td>
<td>Car parts</td>
<td>Yazaki</td>
<td>2012</td>
<td>Japan</td>
<td>International</td>
<td>470</td>
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<td>4</td>
<td>Car parts</td>
<td>Bridgestone</td>
<td>2014</td>
<td>Japan</td>
<td>International</td>
<td>425</td>
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<tr>
<td>5</td>
<td>LCD panels</td>
<td>LG Display</td>
<td>2009</td>
<td>Korea</td>
<td>International</td>
<td>400</td>
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<tr>
<td>6</td>
<td>Air transport</td>
<td>Air France &amp; KLM</td>
<td>2008</td>
<td>France &amp; Netherlands</td>
<td>International</td>
<td>350</td>
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<tr>
<td>7</td>
<td>Air transport</td>
<td>Korean Air</td>
<td>2007</td>
<td>Korea</td>
<td>International</td>
<td>300</td>
</tr>
<tr>
<td>7</td>
<td>Air transport</td>
<td>British Airways</td>
<td>2007</td>
<td>UK</td>
<td>International</td>
<td>300</td>
</tr>
<tr>
<td>7</td>
<td>DRAM</td>
<td>Samsung</td>
<td>2006</td>
<td>Korea</td>
<td>International</td>
<td>300</td>
</tr>
<tr>
<td>10</td>
<td>Vitamins</td>
<td>BASF</td>
<td>1999</td>
<td>Germany</td>
<td>International</td>
<td>225</td>
</tr>
</tbody>
</table>

Source: U.S. Department of Justice, Antitrust Division. Ranking as of September 12, 2016.
# The Vitamin Cartels, 1990–1999

## Global Market Shares (%)

<table>
<thead>
<tr>
<th>Firm</th>
<th>Market</th>
<th>A</th>
<th>B1</th>
<th>B2</th>
<th>B5</th>
<th>B6</th>
<th>B9</th>
<th>B12</th>
<th>C</th>
<th>D3</th>
<th>E</th>
<th>H</th>
<th>Carotinoids</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roche</td>
<td>48</td>
<td>44</td>
<td>54</td>
<td>36</td>
<td>49</td>
<td>39</td>
<td>–</td>
<td>46</td>
<td>43</td>
<td>46</td>
<td>45</td>
<td>83</td>
<td></td>
<td>46</td>
</tr>
<tr>
<td>BASF</td>
<td>30</td>
<td>2</td>
<td>30</td>
<td>21</td>
<td>3</td>
<td>–</td>
<td>–</td>
<td>7</td>
<td>13</td>
<td>28</td>
<td>–</td>
<td>16</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>RP</td>
<td>21</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>62</td>
<td>–</td>
<td>–</td>
<td>13</td>
<td>–</td>
<td>8</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Takeda</td>
<td>–</td>
<td>31</td>
<td>3</td>
<td>12</td>
<td>23</td>
<td>–</td>
<td>26</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>7</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Eisai</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>12</td>
<td>–</td>
<td>–</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Daiichi</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>29</td>
<td>12</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>E. Merck</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>5</td>
<td>–</td>
<td>–</td>
<td>10</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>10</td>
<td>–</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Hoechst</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>7</td>
<td>–</td>
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<td>–</td>
<td>1</td>
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<tr>
<td>Others</td>
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<td>–</td>
<td>–</td>
<td>35</td>
<td>–</td>
<td>44</td>
<td>42</td>
<td>–</td>
<td>9</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Cartel total</td>
<td>90</td>
<td>77</td>
<td>87</td>
<td>86</td>
<td>81</td>
<td>97</td>
<td>69</td>
<td>89</td>
<td>100</td>
<td>99</td>
<td>97</td>
<td>100</td>
<td>93</td>
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<tr>
<td>Non-cartel</td>
<td>1</td>
<td>23</td>
<td>13</td>
<td>14</td>
<td>19</td>
<td>3</td>
<td>31</td>
<td>11</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td></td>
<td>7</td>
</tr>
</tbody>
</table>

*Source: Connor (2007, 2008).*
THE VITAMIN CARTELS, 1990–1999

- **Primary evidence (paper trail)**
  - FBI investigation and DOJ prosecution in 1999, plus:
    - Civil litigations in America (*Bernheim 2002*)
    - EC enforcement in 2001 (*EC 2003*)
  - UK Competition Commission’s report (*UKCC 2001*)
    - BASF acquired *Takeda*’s vitamin business *after* the cartel

- **Secondary evidence**
  - Books by economists who worked on the cases:

⇒ **Mission possible!**
  - Build a dataset and estimate *stage-game payoffs*
  - Get direct evidence on firms’ *strategies and beliefs*
  - Use a repeated game to quantify the *incentives to collude*
  - Simulate how they change with *demand, fringe, & merger*
THEORETICAL LITERATURE

- Characterization of perfect public equilibrium (PPE)
  - Abreu, Pearce, & Stacchetti (‘90)
  - Abreu (‘88), Levin (‘03), Fuchs (‘07), Athey & Bagwell (‘08)

- Folk Theorem
  - Fudenberg & Maskin (‘86), Fudenberg, Levine, & Maskin (‘94)

- Effect of communication
  - Kandori & Matsushima (‘98)

- “Real world” strategies
  - Harrington & Skrzypacz (‘07, ‘11)

- Theorists are curious about:
  - How do cartels coordinate on the equilibrium strategy?
  - What is the punishment strategy?
  - What is the monitoring?
EMPIRICAL LITERATURE

- Assessing the usefulness of repeated game models
  - Public monitoring
    - **This paper:** *When do cartels break down?*
  - Imperfect public monitoring in “noisy” Cournot
    - Porter ('83), Ellison ('94): *When do price wars occur?*
  - Transfers via delayed price adjustments
    - Clark & Houde ('13)

- Describing real-world cartels
  - Harrington ('06), Levenstein & Suslow ('06, '11, '14), Connor ('07, '08), Kaplow ('13), Marshall & Marx ('14)

- See also
  - Measuring the outcomes ("conduct") *without* specifying a repeated game
    - Iwata ('74), Bresnahan ('82, '87), Scott-Morton ('97), Genesove & Mullin ('98), Corts ('99), Berry & Haile ('14), Miller & Weinberg ('16)
  - Simulating dynamic oligopoly with collusion
    - Fershtman & Pakes ('00), de Roos ('01, ‘04, ‘06)
  - Auction “bid rigging” & its detection
    - Asker ('10), Kawai & Nakabayashi ('15)
QUESTION

- Why did some cartels survive for a decade while others collapsed after only a few years?

**Road Map**

1. **Data & Industry**

2. **Theory & Empirics**

3. **Findings**
   
   (A) *Who killed the vitamin C cartel?*
   
   (B) *Would BASF-Takeda merger have helped?*

**Background**

- **Dr. B. Douglas Bernheim**, expert witness and Stanford economist
- Report written in 2002 for the plaintiffs (= 4,000+ buyers of bulk vitamins)
- Multi-district class-action litigations, consolidated at the U.S. District Court for the District of Columbia
- Included in jury trials in 2003, which made it publicly available

**U.S. District Court for the District of Columbia**

(November 3, 2016)

Boxes full of documents

I was about to give up
Vitamin C: Price & Cost

Price and Cost

- Cartel Period
- Roche's U.S. Transaction Price
- Roche's Unit Cost

VITAMIN C: PRICE & COST

1  Transaction prices
   - **Homogeneous goods**
   - Multiple concentration grades are aggregated at “100% basis” (i.e., pure crystals)

VITAMIN C: PRICE & COST

① Transaction prices
- **Homogeneous goods**
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② Internally used unit cost data
- Includes the costs of labor, raw materials, & intermediate inputs
- **Hard capacity** was never binding, with utilization rate around 70%.
- **Depreciation** hits SGA expenses, not COG, in terms of accounting.
- Dr. Bernheim was the plaintiffs’ expert, so incentivized to use low cost.

Vitamin C: Price & Cost

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③ Markup
- Homogeneous goods and $N > 2$, hence data reject Bertrand model.
- Cournot seems more suitable, with Kreps & Scheinkman (’83) interpretation
- Soft capacity setting & price competition in every period: Production plans need time-to-execute (e.g., work shifts; ordering & procuring raw materials and intermediates)

**Vitamin C: Production by Firm**

![Graph showing vitamin C production by firm from 1980 to 1998.](image)

VITAMIN C: PRODUCTION BY FIRM

1. Demand growth
   - Both $P$ & $Q$ ↑
   - Suggests $X$ ↑

Vitamin C: Production by Firm

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   - Reduced in 1991–95

**Vitamin C: Production by Firm**

1. **Demand growth**
   - Both $P$ & $Q$ ↑
   - Suggests $X$ ↑

2. **Cartel output**
   - Reduced in 1991–95

3. **Fringe output**
   - Sudden ↑ from 1992

PRODUCT CHARACTERISTICS

- Each vitamin constitutes a separate market.
  - Demand side: Unique metabolic functions
  - Supply side: Unique manufacturing processes

- Homogeneous within each vitamin
  - Price is king in wholesale bulk chemicals.
  - No differentiation across producers
  - Widely viewed as commodities

- Geographically globally market
  - Value >>> transport cost & import tariffs
  - Cross-border arbitrage by independent traders

DEMAND

Why we need vitamins
- Avoidance of deficiency symptoms
- Broader “health benefits” for humans
  - 92% of vitamin C and β-carotene is for human use.
- Animal nutrition
  - 87% of vitamin A, and 73% of vitamin E, are for animals.

Steady growth
- Population of humans and animals; GDP per capita
- “Perceived benefits” and “educational marketing”
- Sophistication of animal husbandry

Many small buyers
- 4,000+ class plaintiffs; 9,000+ purchasers
- Manufacturers of feeds, foods/beverages, and drugs
- Farmers, cooperatives, and premix blenders
  - Even Coca-Cola is only 2.14% of the vitamin C market.

DIFFERENT STROKES FOR DIFFERENT FOLKS

Figure 6-2: Premix composition by value

Source: Roche and BASF transaction data and premix formulations

Source: Bernheim (2002), p. 60.
SUPPLY

- All major suppliers in the cartels
  - About four cartel members in each vitamin
- European “Big Three”
  - Roche (Hoffmann-La Roche): a pioneering Swiss drug company
  - BASF (Badische Anilin und Soda Fabrik): a German chemical giant
  - RP (Rhône-Poulenc): a French chemical maker
- Japanese drug makers
  - Takeda, the largest in Japan, followed by Eisai, Daiichi
  - American companies had exited by the 1980s
    - E.g., Pfizer, Merck, American Home Products
- Mature technologies, stable market structure
  - No major innovations in production processes since 1980
  - No major entry or exit, except for the Chinese fringe

Source: Bernheim (2002); Conner (2007), Global Price Fixing, second edition.
THE CARTELS (I): BEGINNING

“We need to talk”
- June 7, 1989, Basel: Roche × BASF (heads of Vitamin divisions)
  - Met to discuss cooperation in vitamins A & E
- August 1989, Zurich: RP (head of Animal Nutrition division)

Design
- Agreed to freeze market shares in 1988 for “foreseeable future”
- Split predicted 1990 sales proportionally to the quotas
- Meetings
  - Top-level (annual)
  - Middle-level (quarterly)
  - Regional product marketing managers (quarterly)

“Let’s invite other people”
- 1990: Hoechst & Eisai
  - Vitamin B12, beta carotene, canthaxanthin, premixes
- 1991: Daiichi, E. Merck, Takeda + {Sumitomo, Tanabe, Kongo}
  - Vitamins B1, B2, B5, B6, B9, C, H

THE CARTELS (II): OPERATIONS

- **Public monitoring** (with time lag)
  - Self-reported sales data
  - Verified with government trade statistics
    - Published with lag

- **Trigger strategies**
  - Punishment is not officially specified in agreement, but implicit threat of:
    - Reversion to competitive pricing
    - Indefinite breakdown of cartel
      - EC (2003) reports that *the three European producers presented Takeda with an ultimatum: unless it agreed to cut back its vitamin C sales, they would withdraw from the agreement* (p. 44)
  - No indication of:
    - “Multi-market contact” style threats
      - Different cartels collapsed at different times
    - “Carrot-and-stick” or other complicated punishment strategies
      - Prices were stable after the cartels broke up
    - “Price wars as part of equilibrium”
      - Nothing like price wars (until the cartels collapsed permanently)

THE CARTELS (III): END

- Six “natural deaths” in 1994 or 1995
  - Unexpected fringe entry & expansion
    - Chinese state-owned enterprises (SOEs): B1, B6, B9, C
    - Il Sung of Korea: H
    - Archer Daniels Midland (ADM) & Coors Biotech: B2
  - August 24, 1995: Final meeting of vitamin C cartel

- Ten “forced terminations” in 1998 or 1999
  - Late 1996: ADM to cooperate with DOJ in the citric acid cartel case
  - March 1997: FBI interviewed Dr. Kuno Sommer who denied it all
  - March 1998: Boies & Schiller law firm filed civil price-fixing suit
  - Summer 1998: Lonza (B3) & Bio-Products (B4) to cooperate with FBI
  - January 1999: RP applied for Corporate Leniency Program
  - February 1999: RP managers tape-recorded the cartel meeting
    - Roche & BASF pled guilty and agreed to pay $725 million fines

- Mergers
  - Antitrust clearing of RP’s merger with Hoechst to become Aventis
  - Antitrust clearing of BASF’s acquisition of Takeda’s vitamin businesses in 2001

ROAD MAP

1. DATA & INDUSTRY

2. THEORY & EMPIRICS
   Step 1: Demand & Cost
   Step 2: Profits
   Step 3: Values
   Robustness

3. FINDINGS
   (A) Who killed the vitamin C cartel?
   (B) Would BASF-Takeda merger have helped?
**Step 1**

**Estimating Demand & Costs: How To**

- **Linear demand**
  \[ Q_t^D = \alpha_0 + \alpha_1 P_t + \alpha_2 X_t + \varepsilon_t, \]  

- **Cournot FOC**
  \[ P_t + \frac{\partial P}{\partial Q} q_{i,t} = c_{i,t}, \]

- **Effective demand shifter**
  \[ \hat{X}_t = \alpha_0 + \alpha_2 X_t + \varepsilon_t, \]

- **Identification tradeoff**
  - **Benefit:** No need to rely on demand specification & true \( X \)
  - **Cost:** Need to know regimes in data & to model supply side
  - In our context: **Benefit >>> Cost \approx 0**
**STEP 1**

**ESTIMATING DEMAND: RESULTS**

**Price-elasticity**

**Effective Demand Shifter**

![Price-elasticity of Demand](image1)

![Demand Shifter](image2)
Step 2
Calculating Prices & Profits: How To

- **Profits**
  \[ \pi_{i,\tau,t} = (P_{\tau,t} - c_{i,t}) q_{i,\tau,t}, \]  \hspace{1cm} (7)

- **Three cases**
  - \( \pi^C_{i,\tau,t} \) **Cartel** maximizes its joint profit via quotas
    - Its target price is “monopoly” price
  - \( \pi^D_{i,\tau,t} \) **Deviation** (non-compliance) for 3 periods
    - Lagged public monitoring
  - \( \pi^N_{i,\tau,t} \) **Static Nash** if someone has ever cheated
    - Punishment (trigger strategy)
Step 2
Calculating Prices & Profits: Results

Cartel ≠ Monopoly Price  Collude, Defect, or Nash

Monopoly & Nash Prices

Roche's Profits

($/kg)  ($ million)
STEP 3
VALUES & INCENTIVES: HOW TO

- Payoff if comply with the cartel agreement
  \[ V_{i,\tau|t}^{C} = \sum_{s \geq \tau} \beta^{s-\tau} \pi_{i,s|t}^{C} \]  

- Payoff if not comply
  \[ V_{i,\tau|t}^{D} = \sum_{s = \tau}^{\tau+2} \beta^{s-\tau} \pi_{i,s|t}^{D} + \sum_{s \geq \tau+3} \beta^{s-\tau} \pi_{i,s|t}^{N} \]  

- Incentive compatibility constraint (ICC)
  - The trigger strategy is equilibrium iff
  \[ \min_{i \in I, \tau \geq t} (V_{i,\tau|t}^{C} - V_{i,\tau|t}^{D}) \geq 0. \]
**STEP 3**

**VALUES & INCENTIVES: HOW TO**

(1000 kg)

**Demand Shifter**

- Cartel Period
- Residual
- Fitted Time Trend (polynomial)
**STEP 3**

**VALUES & INCENTIVES: HOW TO**

---

*Note:* The explosion mark in 1992 represents the NATO bombing of vitamin C plants in Bosnia, which ignited the Chinese industrial policy.  
*Source:* EC (2003), Bernheim (2002).
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**STEP 3**

**VALUES & INCENTIVES: RESULTS**

\[ \Delta V_{i,\tau|t} \equiv V_{i,\tau|t}^C - V_{i,\tau|t}^D \]

- **Actual Cartel Period**
- Prediction as of Jan-1991
- Prediction as of Jan-1992
- Prediction as of Jan-1993
- Prediction as of Jan-1994
- Prediction as of Jan-1995

($ million)
**Step 3**

**Values & Incentives: Results**

\[ \Delta V_{i,t} = \min_{\tau \geq t} \Delta V_{i,\tau|t} \]

- Actual Cartel Period
- \( \text{Beta} = 0.7 \)
**STEP 3**

**VALUES & INCENTIVES: RESULTS**

\[ \Delta V_{i,t} = \min_{\tau \geq t} \Delta V_{i,\tau|t} \]

- Actual Cartel Period
- Beta = 0.9
- Beta = 0.8
- Beta = 0.7
- Beta = 0.6
- Beta = 0.5

($ million)
…MEANWHILE IN OTHER VITAMIN MARKETS
ROBUSTNESS 1: RENEGOTIATION & ENDOGENOUS FRINGE

Could the cartel renegotiate, agree on “better” quotas, and avoid collapse?
  • No

Do results change if Chinese SOEs’ entry & expansion are modeled as endogenous response to the cartel?
  • No

Could it be that the cartel:
  i. rationally expected the Chinese SOEs’ supply responses, and
  ii. set dynamically optimal prices (i.e., limit pricing) to deter the Chinese entry?
  • No

For details, see section 5.4 & Appendix A
ROBUSTNESS 2: ADAPTIVE EXPECTATIONS

Demand Forecast

Roche’s Incentive
**Robustness 3: Differentiated Products?**

- Alternative models of demand & supply
  - Differentiated products
  - Bertrand competition
  - “...because everyone is doing it in Empirical IO”

- Presented (similar) results at Yale
Robustness 3: Differentiated Products?

- Alternative models of demand & supply
  - Differentiated products
  - Bertrand competition
  - “...because everyone is doing it in Empirical IO”

- Presented (similar) results at Yale
  - But then Prof. Steven T. Berry, who claims to be the “world’s most pro-differentiated product person,” told us:
    - ...that he really believed bulk chemicals were homogeneous-good Cournot industries,
    - ...that it would be “totally crazy” to use a differentiated-product demand model, and
    - ...that we simply “shouldn’t do it.”
      - So we don’t.
**Road Map**

1. Data & Industry

2. Theory & Empirics
   - Step 1: Demand & Cost
   - Step 2: Profits
   - Step 3: Values
   - Robustness

3. Findings
   - (A) Who killed the vitamin C cartel?
   - (B) Would BASF-Takeda merger have helped?
Let’s compare the following counterfactuals:

- The cartel’s “dream world” scenario, in which
  - Fringe supply had stopped growing after 1994; and
  - Demand growth had not slowed down after 1994.
  - Let’s call it Scenario #1

- But things happened:
  - Scenario #1 – “no China” dream = Scenario #2
  - Scenario #1 – “no slow-down” dream = Scenario #3

- And the reality:
  - Scenario #1 – ALL DREAMS = Actual
FINDING 1  
WHO KILLED THE VITAMIN C CARTEL?

\[ \Delta V_{i,t} \equiv \min_{r \geq t} \Delta V_{i,r|t} \]  

($ million)

- Actual Cartel Period
- Scenario 1  (Demand slowdown = NO; Fringe growth = NO)
- Scenario 2  (Demand slowdown = NO; Fringe growth = YES)
- Scenario 3  (Demand slowdown = YES; Fringe growth = NO)
- Actual       (Demand slowdown = YES; Fringe growth = YES)
Finding 2
If BASF-Takeda Merger Before 1991

- Would this merger have helped prolong the life of the vitamin C cartel?

- Answering this question requires the measurement of the ICC

\[ \Delta V_{i,t} \equiv \min_{\tau \geq t} \Delta V_{i,\tau | t} \]

- ...under the new market structure with 3 firms: Roche, E. Merck, & BASF-Takeda
- ...with hypothetical cartel quotas based on 3-firm Nash market shares as of 1990.

- According to the merger report by the U.K. Competition Commission (‘01), Takeda’s vitamin C plants were more efficient than BASF’s, and BASF planned to retire its own plants.
  - The merged BASF-Takeda inherits Takeda’s marginal costs.
**Finding 2**

**If BASF-Takeda Merger Before 1991**

\[ \Delta V_{i,t} = \min_{\tau \geq t} \Delta V_{i,\tau | t} \]

($\text{million}$)
FINDING 2
IF BASF-TAKEDA MERGER BEFORE 1991

\[
\sum_{s \geq \tau + 3} \beta^{s-1} \pi_{i,s|t}^C - \sum_{s \geq \tau + 3} \beta^{s-1} \pi_{i,s|t}^N \geq \sum_{s = \tau}^{\tau+2} \beta^{s-1} \pi_{i,s|t}^D - \sum_{s = \tau}^{\tau+2} \beta^{s-1} \pi_{i,s|t}^C
\]

on-path continuation value punishment continuation value (gross) deviation gain forgone on-path gain

Table 4: Accounting for Changes in the IC Constraint

<table>
<thead>
<tr>
<th>($\text{million}$)</th>
<th>No merger (1)</th>
<th>Merger (2)</th>
<th>Change (3) = (2) - (1)</th>
<th>Contribution to IC (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period (\tau) that minimizes (\Delta V_{\tau</td>
<td>\text{Aug.-'95}})</td>
<td>Feb-1996</td>
<td>Dec-1996</td>
<td></td>
</tr>
<tr>
<td>On-path cont. value ((V^1))</td>
<td>93.3</td>
<td>97.9</td>
<td>+4.5</td>
<td>78.6%</td>
</tr>
<tr>
<td>Punishment value ((V^2))</td>
<td>91.8</td>
<td>91.2</td>
<td>-0.6</td>
<td>10.4%</td>
</tr>
<tr>
<td>Gross deviation gain ((V^3))</td>
<td>14.3</td>
<td>11.7</td>
<td>-2.6</td>
<td>45.5%</td>
</tr>
<tr>
<td>Short-run on-path gain ((V^4))</td>
<td>12.8</td>
<td>10.9</td>
<td>-2.0</td>
<td>-34.5%</td>
</tr>
<tr>
<td>Net on-path cont. value ((V^1 - V^2))</td>
<td>1.6</td>
<td>6.7</td>
<td>+5.1</td>
<td>89.0%</td>
</tr>
<tr>
<td>Net deviation gain ((V^3 - V^4))</td>
<td>1.5</td>
<td>0.8</td>
<td>-0.6</td>
<td>11.0%</td>
</tr>
<tr>
<td>IC constraint: ((V^1 - V^2) - (V^3 - V^4))</td>
<td>0.1*</td>
<td>5.9</td>
<td>+5.8</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Note: The IC constraint and its components as of August 1995 with \(\beta = 0.7\). Note the baseline IC constraint is not exactly zero (0.1), but our narrative in the main text ignores this small numerical difference.
### Finding 2
If BASF-Takeda Merger Before 1991

Welfare Analysis *With* & *Without* Coordinated Effect  
(Annualized Average 1998 Outcomes)

<table>
<thead>
<tr>
<th></th>
<th>No merger (4 firms)</th>
<th>Merger simulation (3 firms)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unilateral effect</strong></td>
<td>–</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Coordinated effect</strong></td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><strong>Price ($/kg)</strong></td>
<td>9.81</td>
<td>9.98</td>
</tr>
<tr>
<td></td>
<td>(±0%)</td>
<td>(+1.7%)</td>
</tr>
<tr>
<td><strong>Output (1000kg)</strong></td>
<td>70,533</td>
<td>69,532</td>
</tr>
<tr>
<td></td>
<td>(±0%)</td>
<td>(▲1.4%)</td>
</tr>
<tr>
<td><strong>Consumer surplus (1000$)</strong></td>
<td>410,255</td>
<td>398,669</td>
</tr>
<tr>
<td></td>
<td>(±0%)</td>
<td>(▲2.8%)</td>
</tr>
</tbody>
</table>
CONCLUSION

Repeated game theory is particularly useful when “right” data & evidence are supplied.
① Explains diverging fates of cartels in reality
② Quantifies the effects of demand & fringe on ICC
③ Predicts the “coordinated effects” of merger

Future research
- Private monitoring
- Tacit collusion
- Antitrust policy when cartels and mergers interact