

MEASURING THE INCENTIVE TO COLLUDE

The Vitamin Cartels, 1990–1999

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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

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

Source: U.S. Department of Justice, Antitrust Division. Ranking as of September 12, 2016.

THE VITAMIN CARTELS, 1990–1999

GLOBAL MARKET SHARES (%)

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

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:
 - [Connor](#), *Global Price Fixing* (2007)
 - [Marshall](#) and [Marx](#), *The Economics of Collusion* (2014)
- ⇒ [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

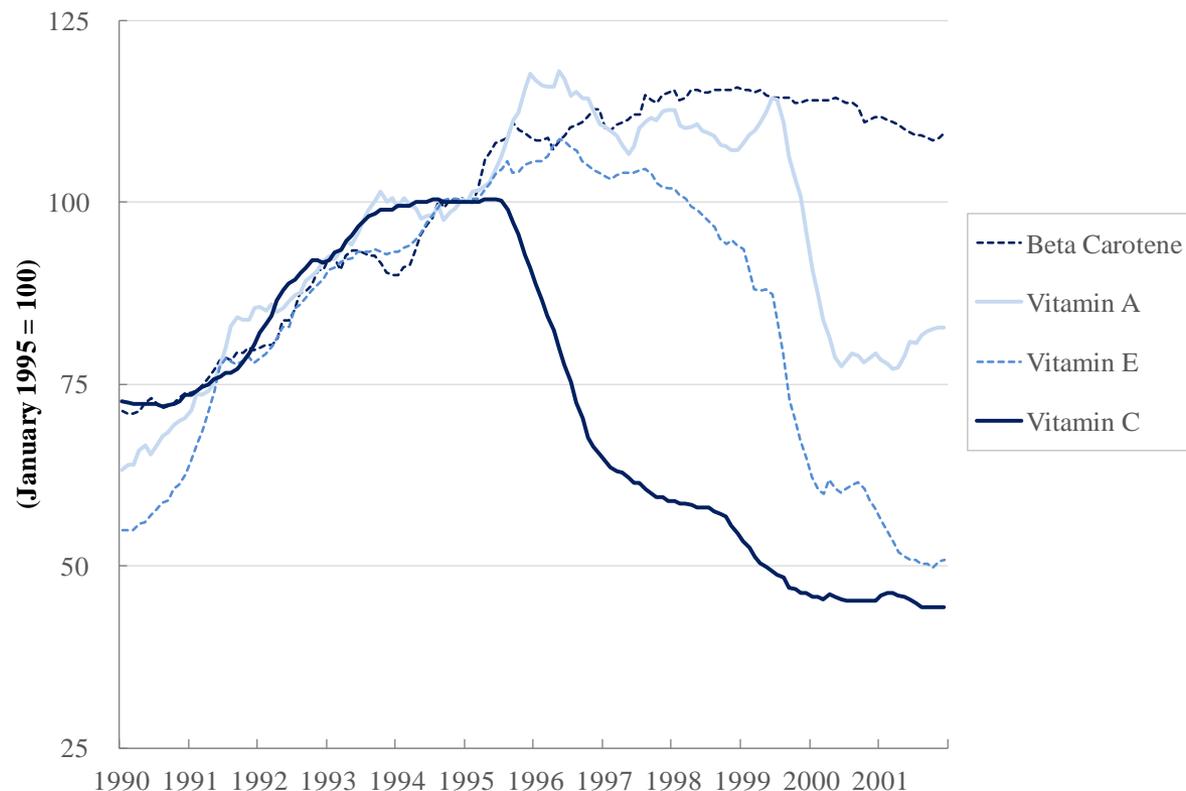
- Characterization of perfect public equilibrium (PPE)
 - Abreu, Pearce, & Stacchetti ('90)
 - Abreu ('88), Levin ('03), Fuchs ('07), Athey & Bagwell ('08)
- Folk Theorem
 - Fudenberg & Maskin ('86), Fudenberg, Levine, & Maskin ('94)
- Effect of communication
 - Kandori & Matsushima ('98)
- “Real world” 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?



Source: Roche ROVIS data from Roche Data Books *cit. in* "Expert Report of B. Douglas Bernheim," *In Re: Vitamins Antitrust Litigation*, MDL No. 1285, Misc 99-0197. We reverse-engineered the price data by digitizing Figures 9-1 through 9-4.

ROAD MAP

1. DATA & INDUSTRY

2. THEORY & EMPIRICS

3. FINDINGS

(A) WHO KILLED THE VITAMIN C CARTEL?

(B) WOULD BASF-TAKEDA MERGER HAVE HELPED?

FINDING THE BERNHEIM REPORT (2002)

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



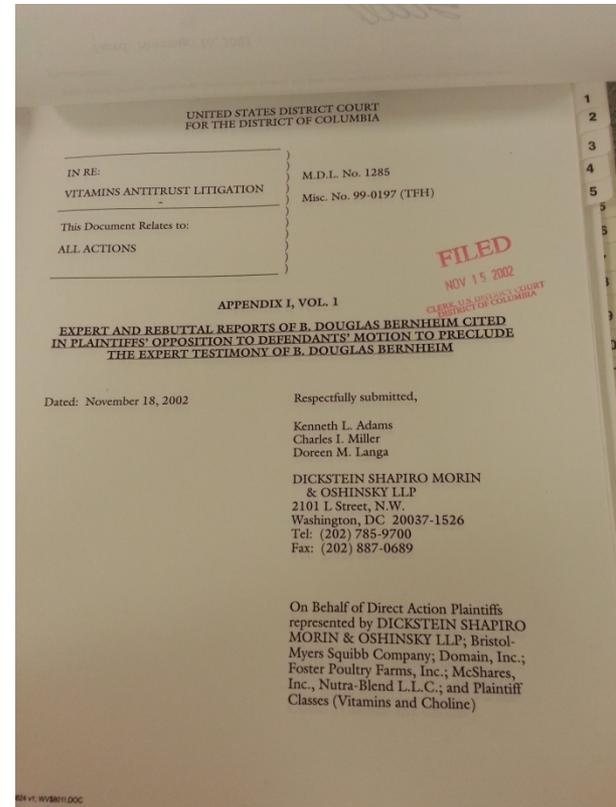
(November 3, 2016)

FINDING THE BERNHEIM REPORT (2002)

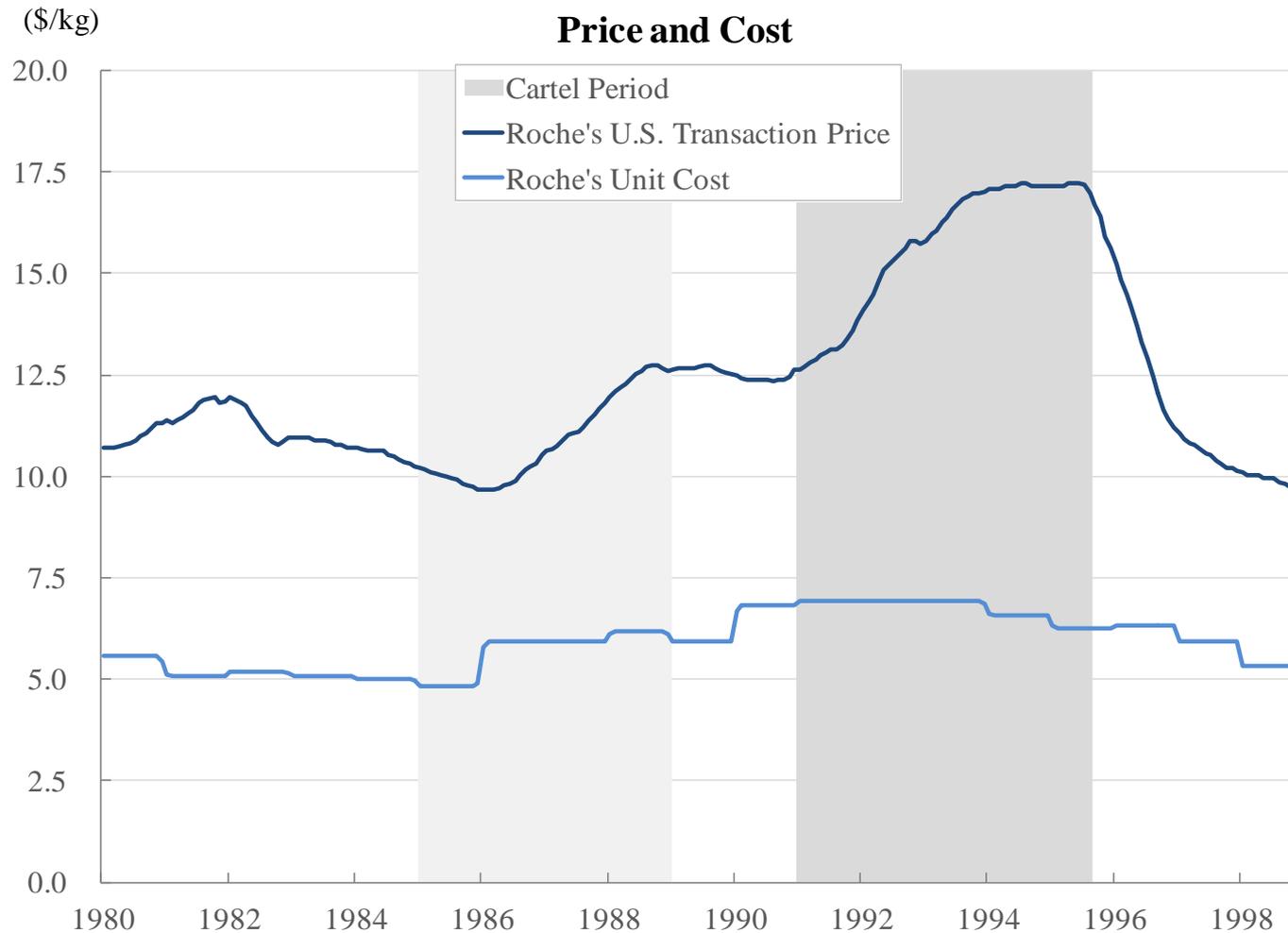
Boxes full of documents



I was about to give up



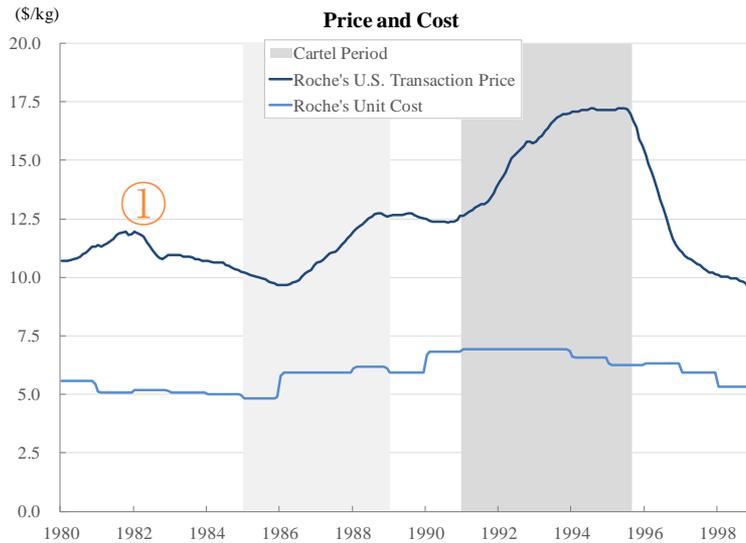
VITAMIN C: PRICE & COST



Source: Roche ROVIS data from Roche Data Books *cit. in* "Expert Report of B. Douglas Bernheim," *In Re: Vitamins Antitrust Litigation*, MDL No. 1285, Misc 99-0197.

VITAMIN C: PRICE & COST

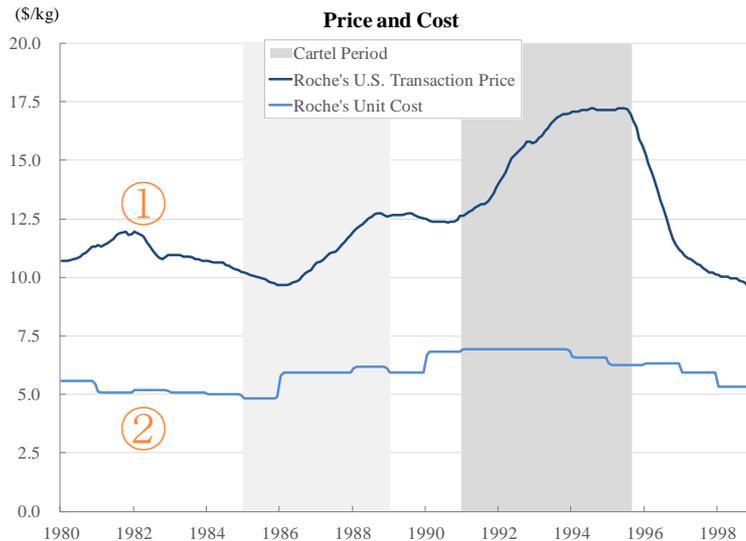
- ① Transaction prices
 - Homogeneous goods
 - Multiple concentration grades are aggregated at “100% basis” (i.e., pure crystals)



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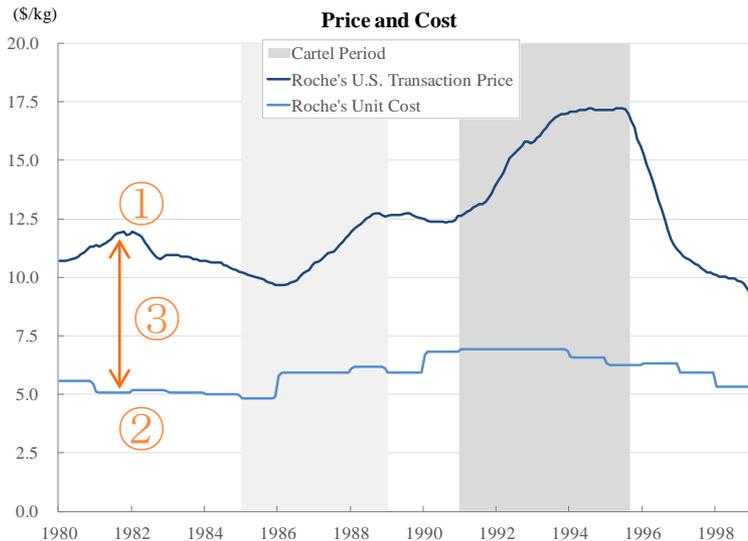
VITAMIN C: PRICE & COST

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



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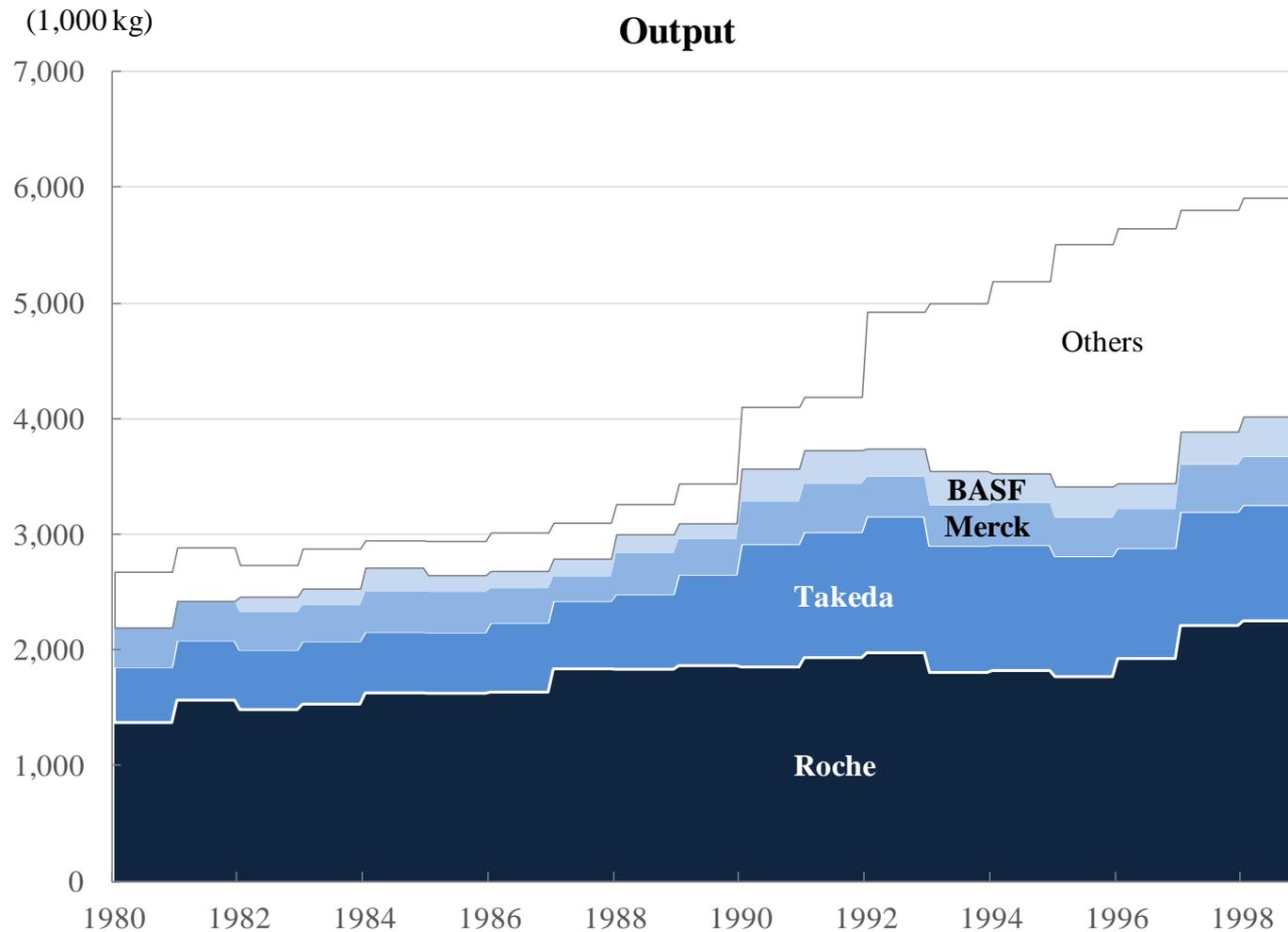
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- ③ Markup
 - Homogeneous goods and $N > 2$, hence data reject Bertrand model.
 - **Cournot** seems more suitable, with Kreps & Scheinkman (‘83) interpretation
 - **Soft capacity** setting & price competition in every period: **Production plans** need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

VITAMIN C: PRODUCTION BY FIRM

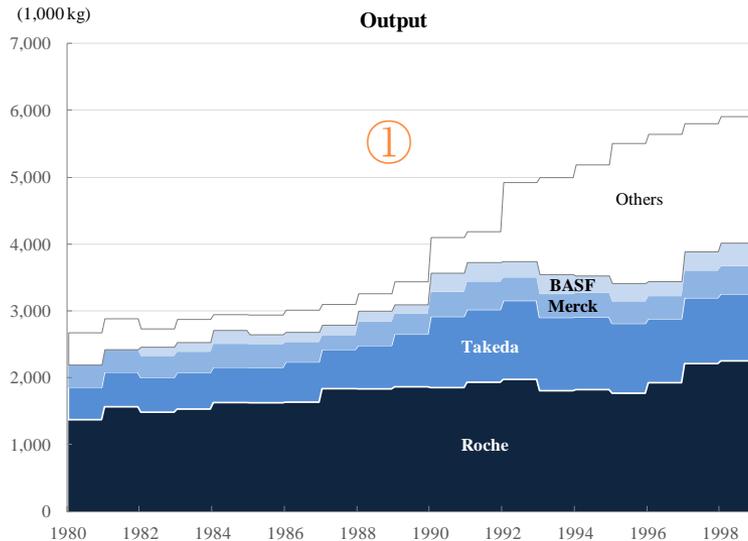


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VITAMIN C: PRODUCTION BY FIRM

① Demand growth

- Both P & Q \uparrow
- Suggests X \uparrow



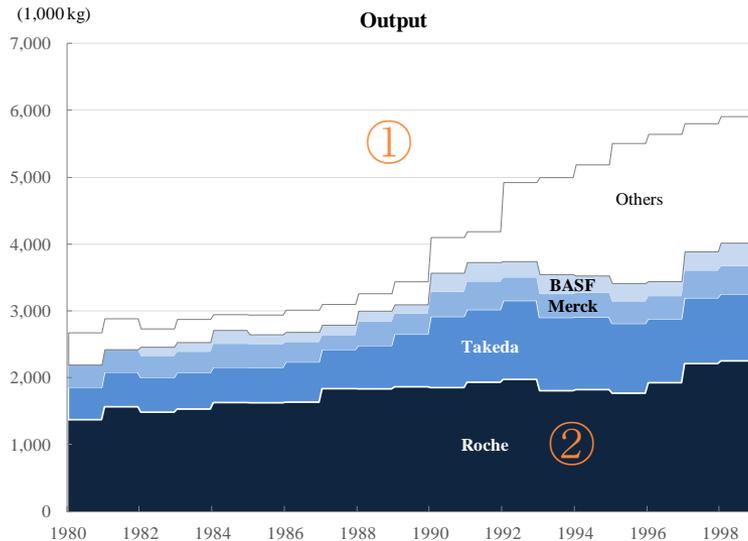
VITAMIN C: PRODUCTION BY FIRM

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② Cartel output

- Reduced in 1991–95



VITAMIN C: PRODUCTION BY FIRM

① Demand growth

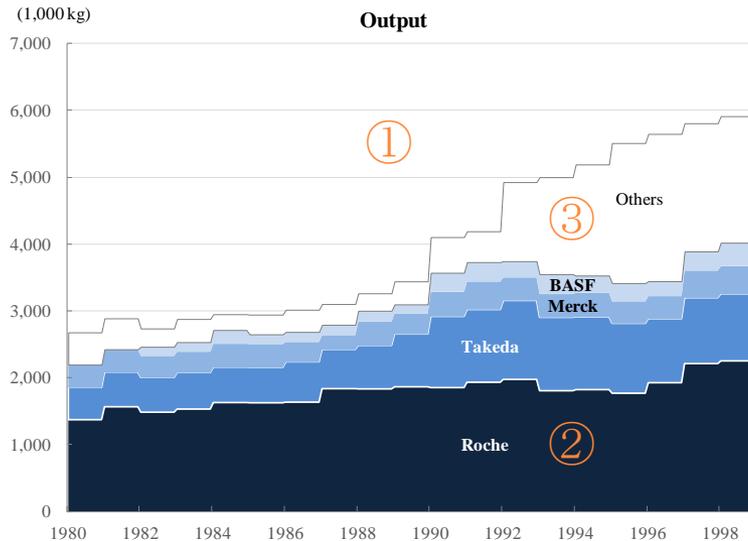
- Both P & Q \uparrow
- Suggests X \uparrow

② Cartel output

- Reduced in 1991–95

③ Fringe output

- Sudden \uparrow from 1992



PRODUCT CHARACTERISTICS

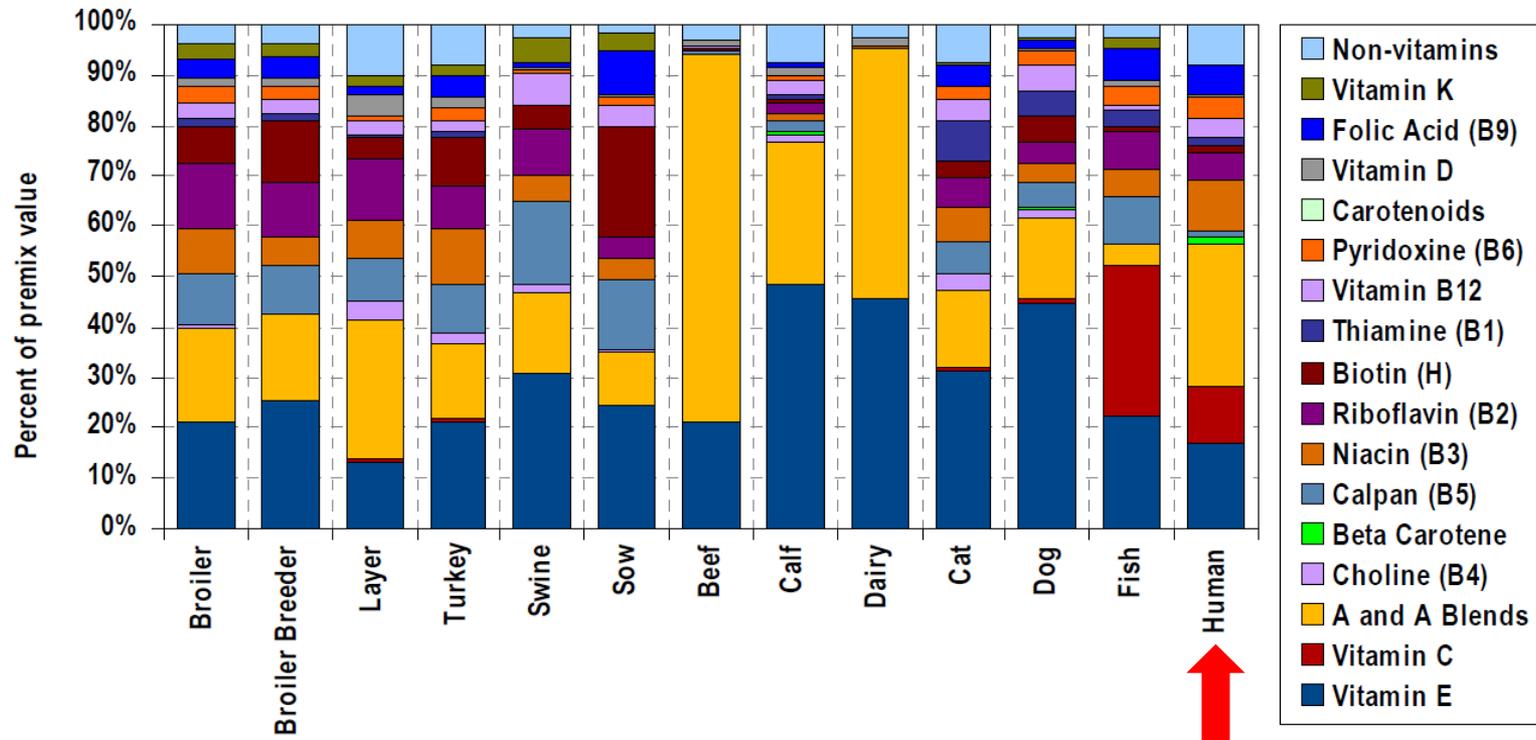
- Each vitamin constitutes a **separate** market.
 - Demand side: Unique metabolic functions
 - Supply side: Unique manufacturing processes
- **Homogeneous** within each vitamin
 - Price is king in wholesale bulk chemicals.
 - No differentiation across producers
 - Widely viewed as commodities
- Geographically **global** 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



You are here

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

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

$$Q_t^D = \alpha_0 + \alpha_1 P_t + \alpha_2 X_t + \varepsilon_t, \quad (4)$$

- Cournot FOC

$$P_t + \frac{\partial P}{\partial Q} q_{i,t} = c_{i,t}, \quad (5)$$

- Effective demand shifter

$$\tilde{X}_t \equiv \alpha_0 + \alpha_2 X_t + \varepsilon_t, \quad (6)$$

- Identification tradeoff

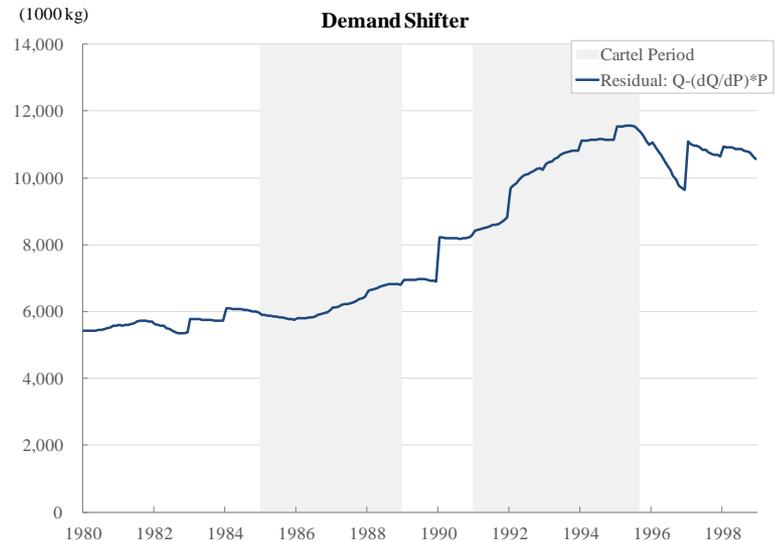
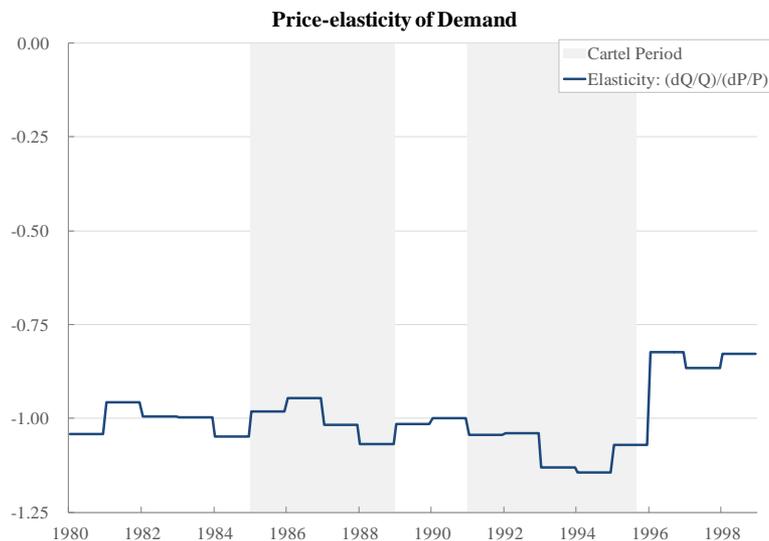
- Benefit: No need to rely on demand specification & true X
- Cost: Need to know regimes in data & to model supply side
- In our context: *Benefit* >>> *Cost* ≈ 0

STEP 1

ESTIMATING DEMAND: RESULTS

Price-elasticity

Effective Demand Shifter



STEP 2

CALCULATING PRICES & PROFITS: HOW TO

○ Profits

$$\pi_{i,\tau|t} = (P_{\tau|t} - c_{i,t}) q_{i,\tau|t}, \quad (7)$$

○ Three cases

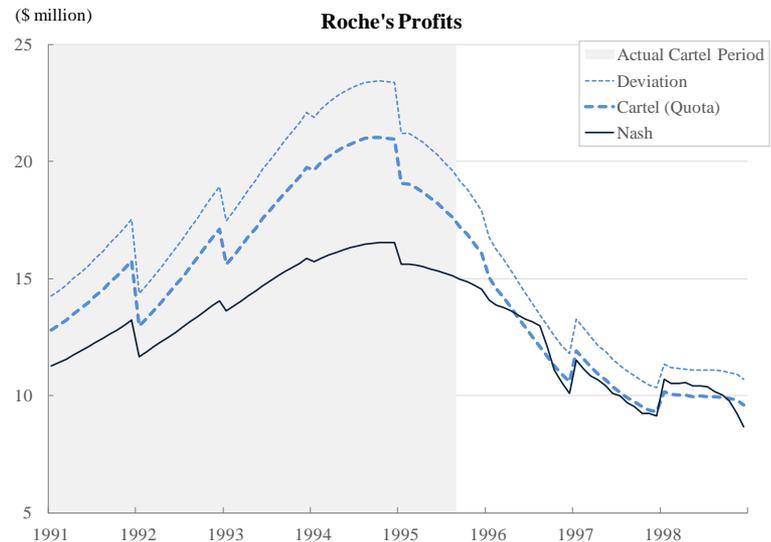
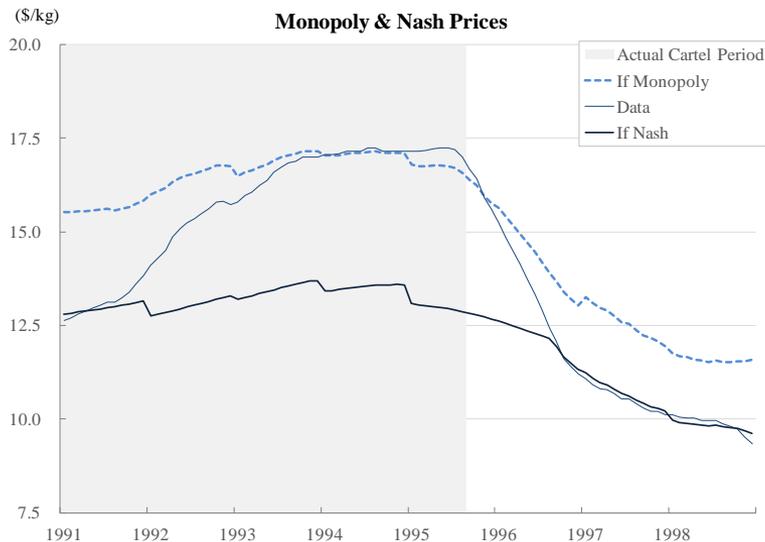
- $\pi_{i,\tau|t}^C$ Cartel maximizes its joint profit via quotas
 - Its target price is “monopoly” price
- $\pi_{i,\tau|t}^D$ Deviation (non-compliance) for 3 periods
 - Lagged public monitoring
- $\pi_{i,\tau|t}^N$ Static Nash if someone has ever cheated
 - Punishment (trigger strategy)

STEP 2

CALCULATING PRICES & PROFITS: RESULTS

Cartel $\hat{=}$ Monopoly Price

Collude, Defect, or Nash



STEP 3

VALUES & INCENTIVES: HOW TO

- Payoff if comply with the cartel agreement

$$V_{i,\tau|t}^C = \sum_{s \geq \tau} \beta^{\tau-1} \pi_{i,s|t}^C, \quad (1)$$

- Payoff if not comply

$$V_{i,\tau|t}^D = \sum_{s=\tau}^{\tau+2} \beta^{s-1} \pi_{i,s|t}^D + \sum_{s \geq \tau+3} \beta^{s-1} \pi_{i,s|t}^N. \quad (2)$$

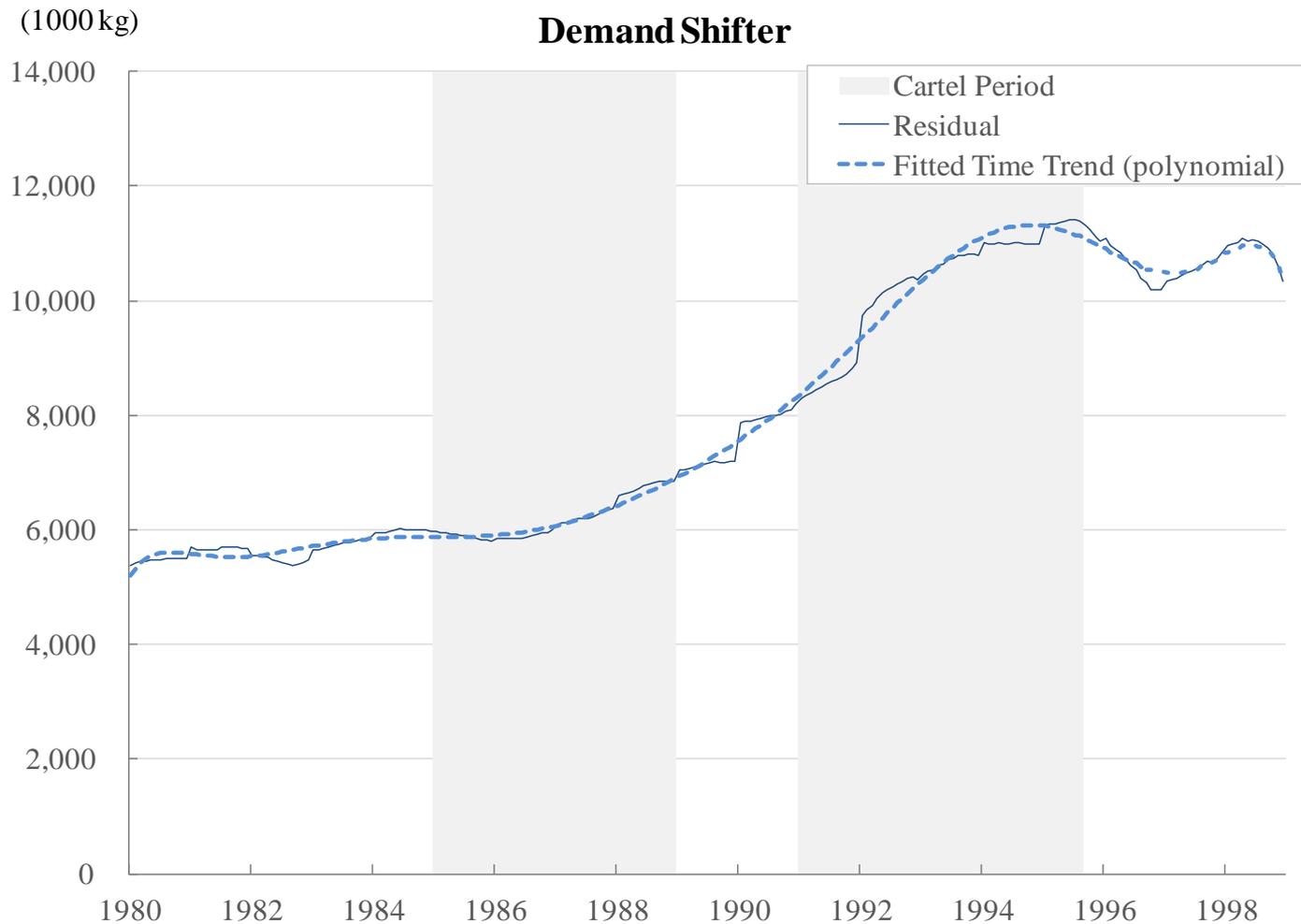
- Incentive compatibility constraint (ICC)

- The trigger strategy is equilibrium iff

$$\min_{i \in I, \tau \geq t} (V_{i,\tau|t}^C - V_{i,\tau|t}^D) \geq 0. \quad (3)$$

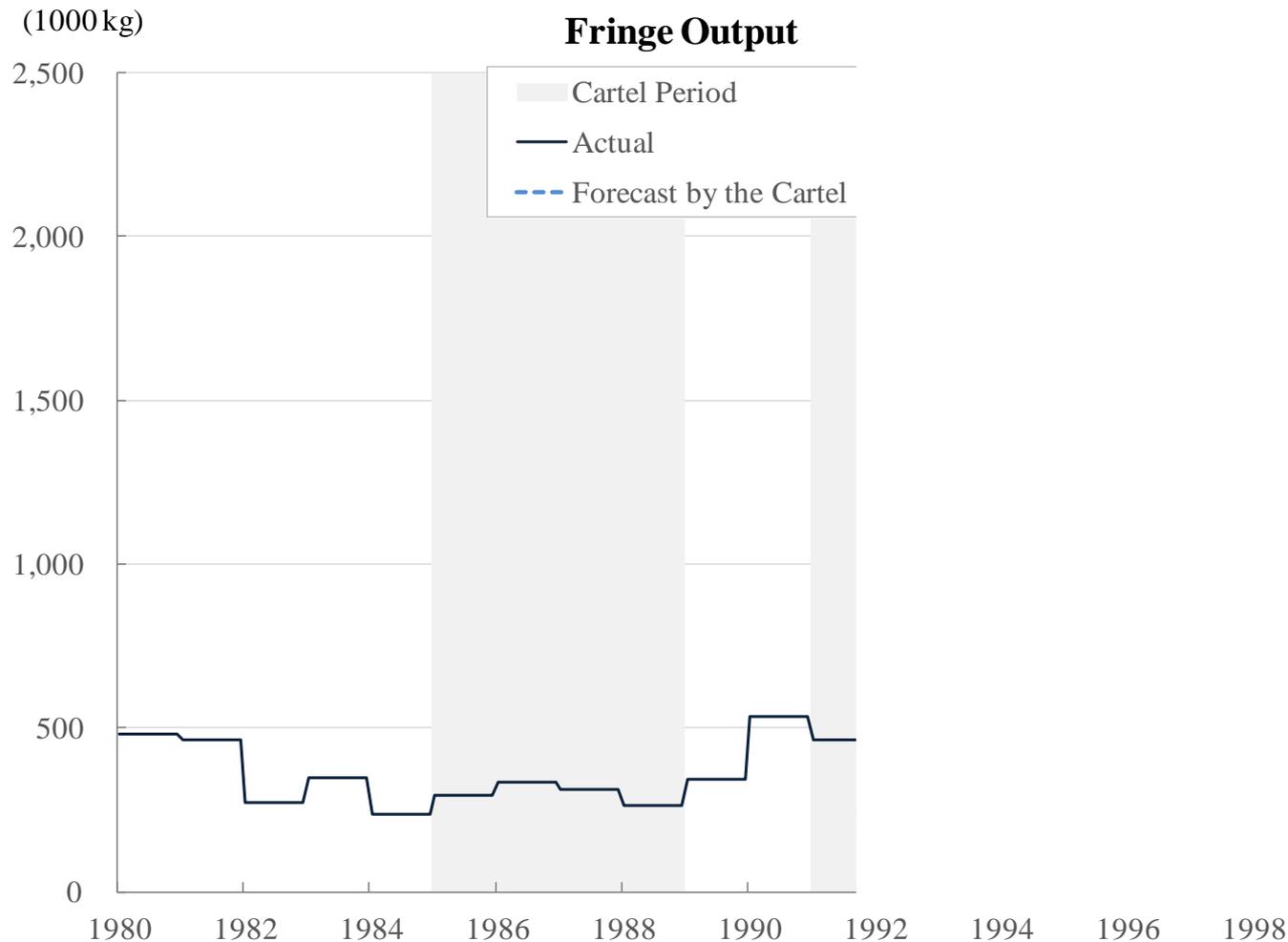
STEP 3

VALUES & INCENTIVES: HOW TO



STEP 3

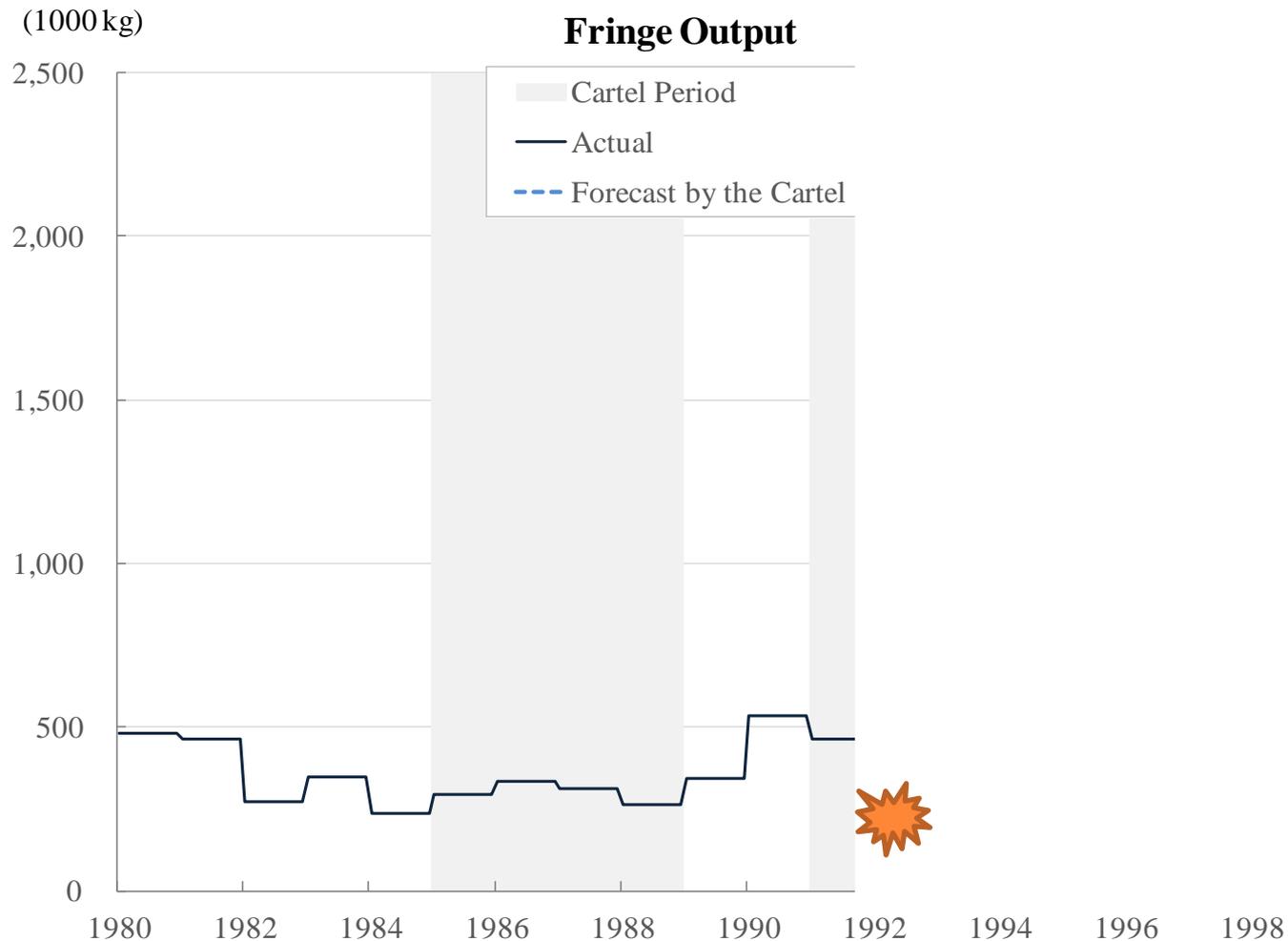
VALUES & INCENTIVES: HOW TO



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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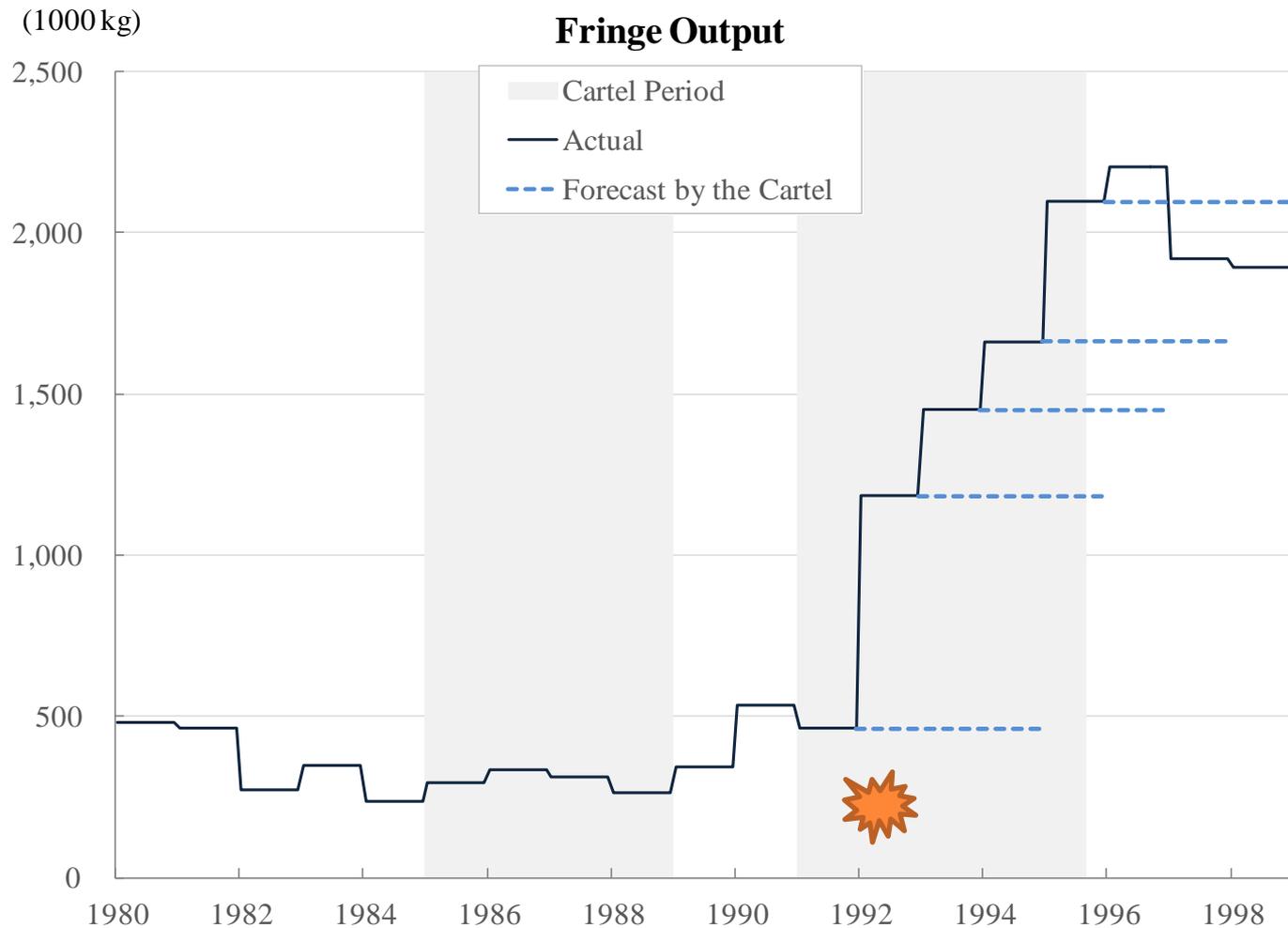
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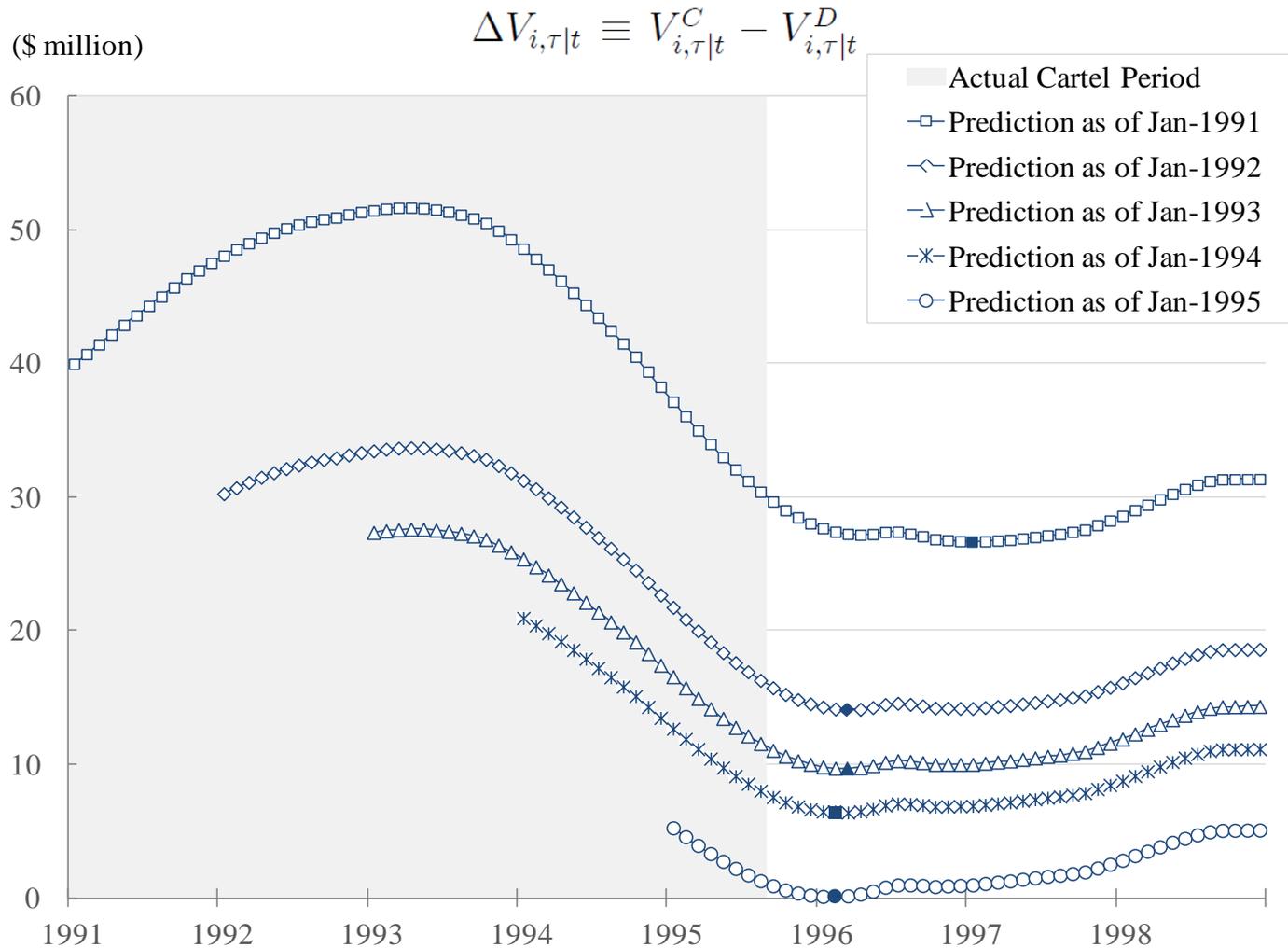
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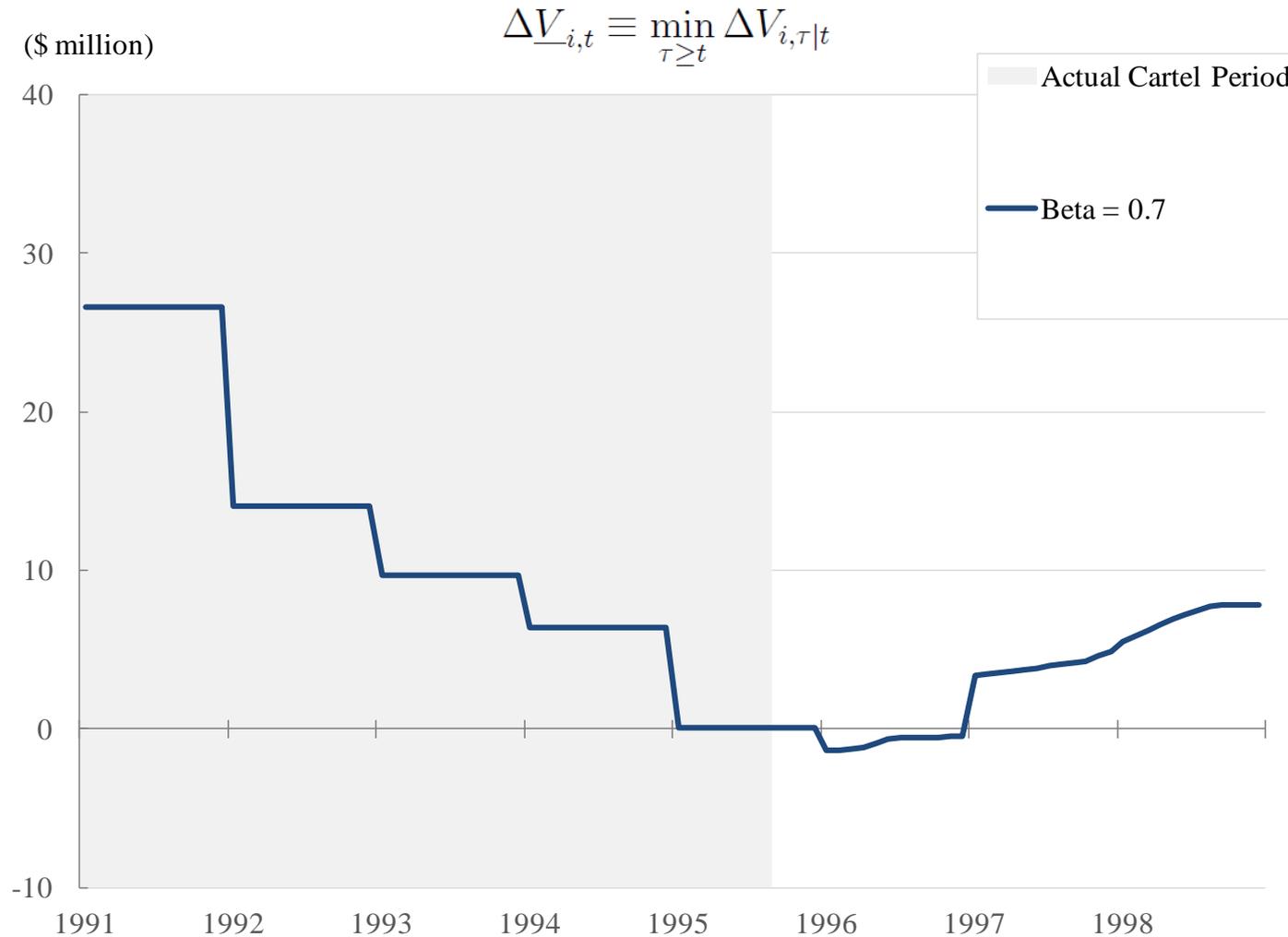
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VALUES & INCENTIVES: RESULTS



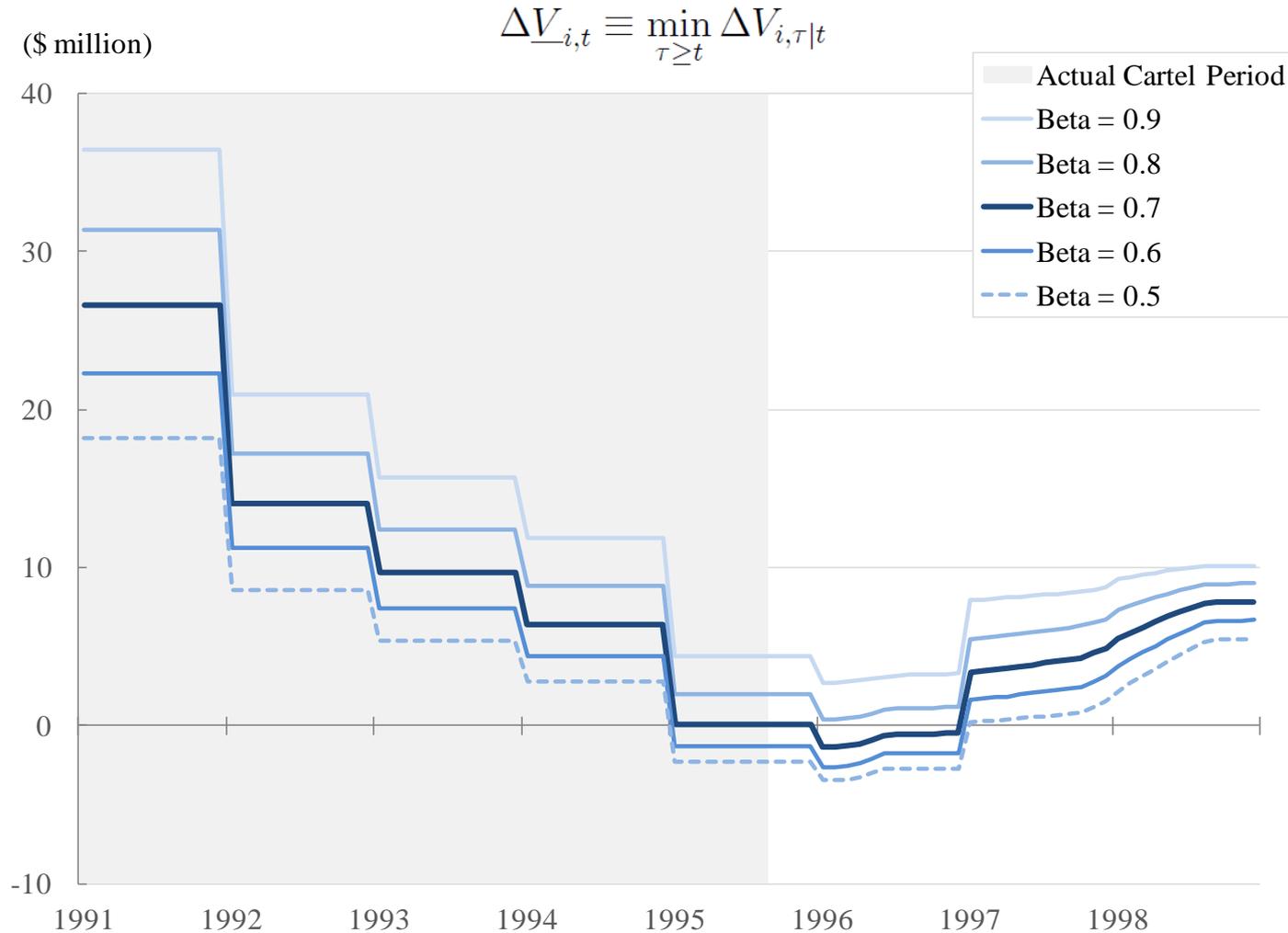
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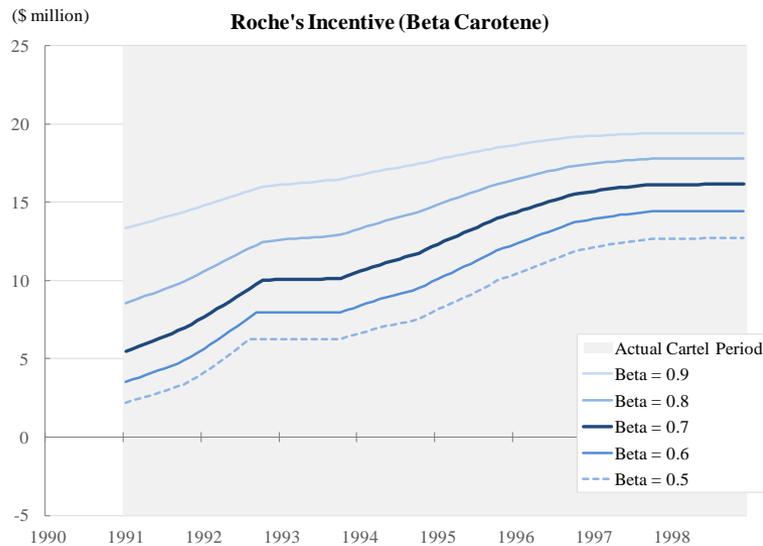
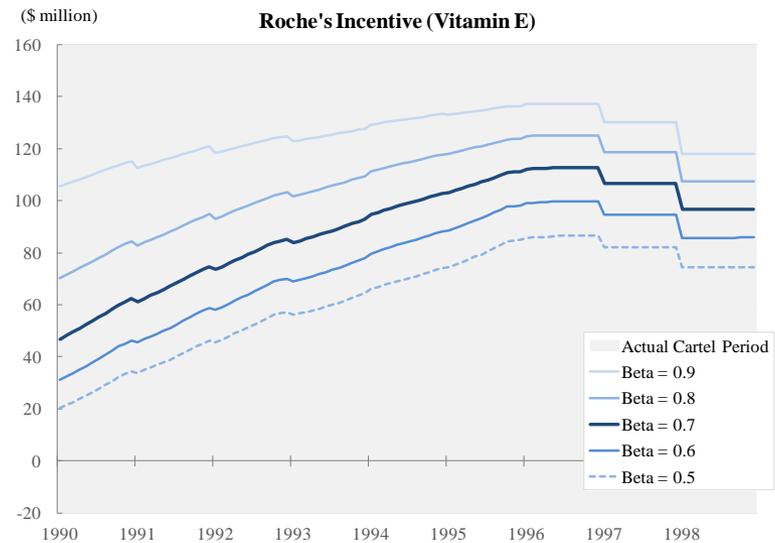
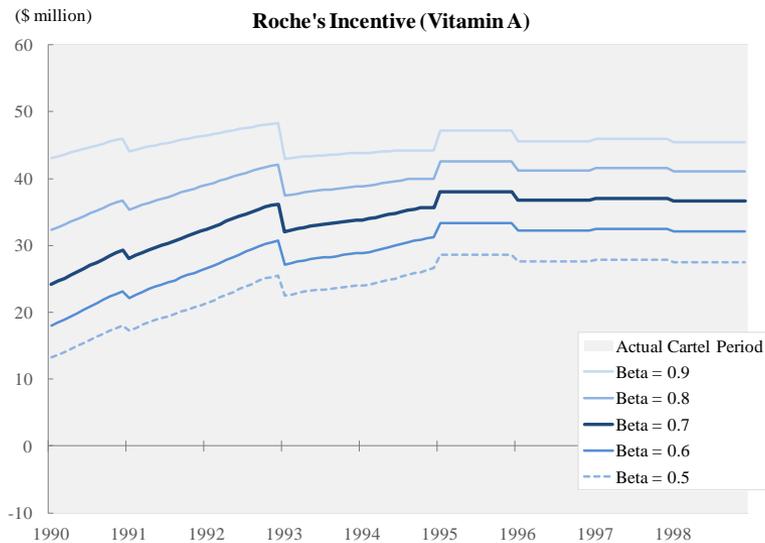


STEP 3

VALUES & INCENTIVES: RESULTS



...MEANWHILE IN OTHER VITAMIN MARKETS

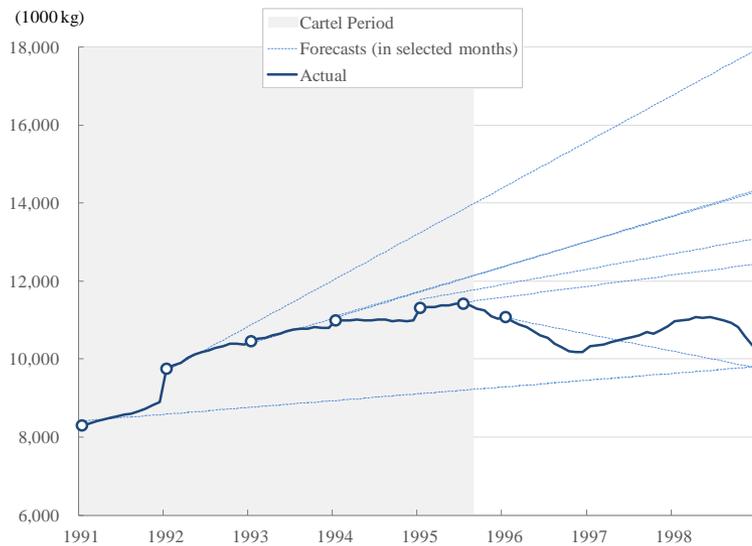


ROBUSTNESS 1: RENEGOTIATION & ENDOGENOUS FRINGE

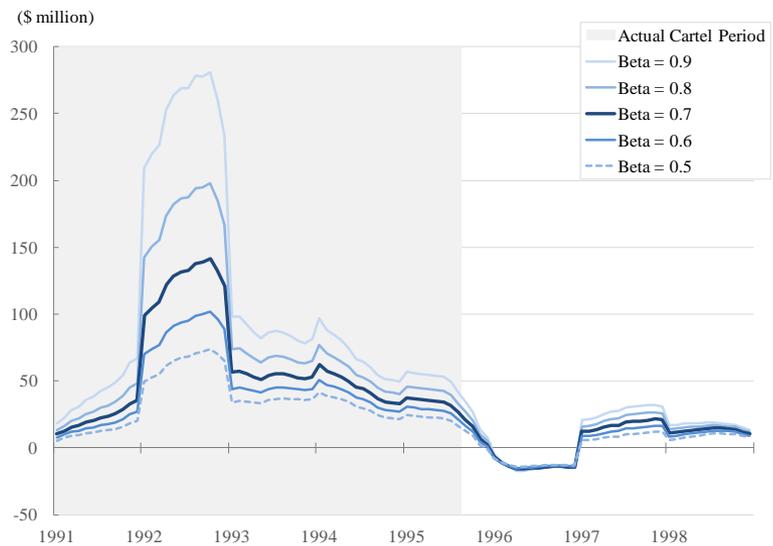
- Could the cartel **renegotiate**, agree on “better” quotas, and **avoid collapse**?
 - No
- Do results change if **Chinese SOEs’ entry & expansion** are modeled as **endogenous response** to the cartel?
 - No
- Could it be that the cartel:
 - i. **rationally expected** the Chinese SOEs’ supply responses, 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.

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(B) WOULD BASF-TAKEDA MERGER HAVE HELPED?

FINDING 1

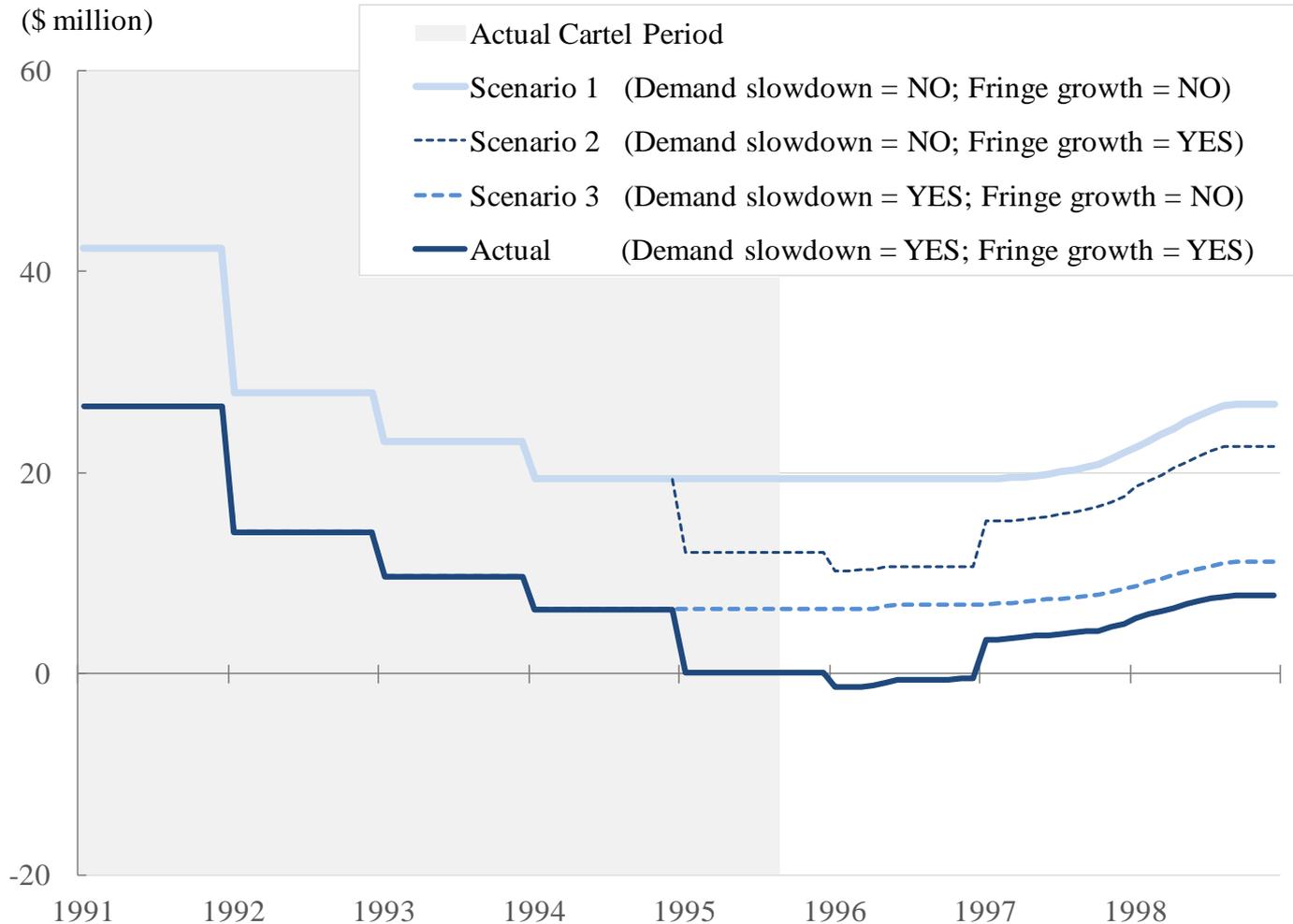
WHO KILLED THE VITAMIN C CARTEL?

- 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?

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



FINDING 2

IF BASF-TAKEDA MERGER BEFORE 1991

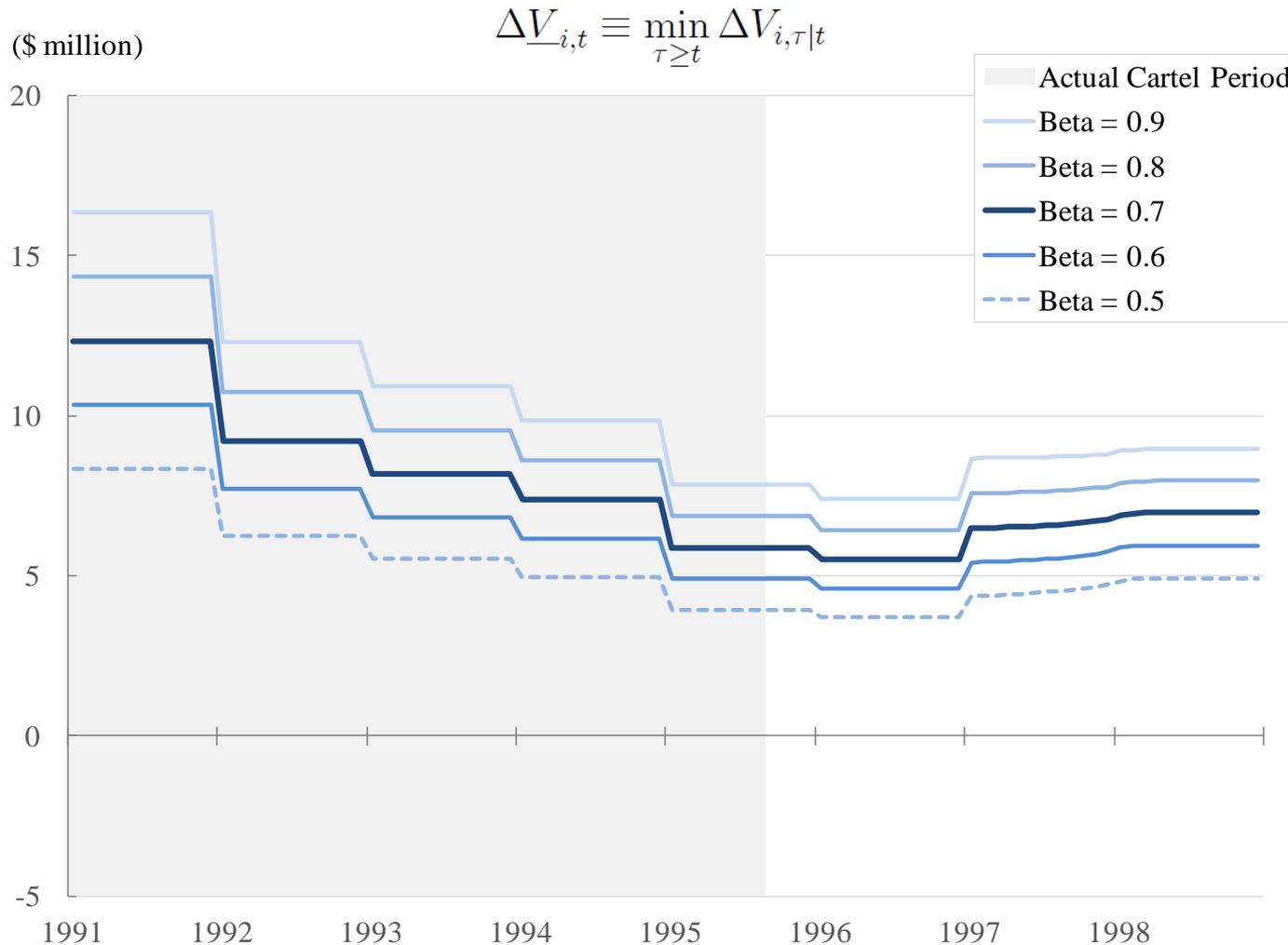
- Would this merger have helped prolong the life of the vitamin C cartel?
- Answering this question requires the **measurement of the ICC**

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

- ...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



FINDING 2

IF BASF-TAKEDA MERGER BEFORE 1991

$$\underbrace{\sum_{s \geq \tau+3} \beta^{s-1} \pi_{i,s|t}^C}_{\text{on-path continuation value}} - \underbrace{\sum_{s \geq \tau+3} \beta^{s-1} \pi_{i,s|t}^N}_{\text{punishment continuation value}} \geq \underbrace{\sum_{s=\tau}^{\tau+2} \beta^{s-1} \pi_{i,s|t}^D}_{\text{(gross) deviation gain}} - \underbrace{\sum_{s=\tau}^{\tau+2} \beta^{s-1} \pi_{i,s|t}^C}_{\text{forgone on-path gain}}$$

Table 4: Accounting for Changes in the IC Constraint

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

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)

	No merger (4 firms)	Merger simulation (3 firms)	
<i>Unilateral effect</i>	–	✓	✓
<i>Coordinated effect</i>	–	–	✓
Price (\$/kg)	9.81	9.98	11.58
	(±0%)	(+1.7%)	(+18.1%)
Output (1000kg)	70,533	69,532	37,875
	(±0%)	(▲1.4%)	(▲46.3%)
Consumer surplus (1000\$)	410,255	398,669	186,683
	(±0%)	(▲2.8%)	(▲68.6%)

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