Building Trust

A Dynamic Game of Collusive Price Leadership

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Understanding the Initiation and Coordination of Collusion

Collusion has been a pivotal topic in industrial organization since Bain (1959), posing significant risks to consumer welfare and market fairness. Despite a rich literature on the implementation phase of collusion Harrington Jr and Chang (2009, 2015); Igami and Sugaya (2021), initiation remains understudied, with some exceptions Byrne and De Roos (2019).[1]

The Oligopolistic Challenge: Firms face two primary issues when aiming for collusion:

- *Incentive Problem* - Ensuring collusion is profitable Harrington (2018).
- *Coordination Problem* - Dealing with multiple equilibria causing uncertainty Harrington (2018).

Modeling Coordination: This research introduces a dynamic game model with incomplete information, extending the MPE framework Ericson and Pakes (1995); Bajari et al. (2007), incorporating 'biased belief functions' to capture trust-building in collusion's early stages.
Trust Building Equilibrium: A novel equilibrium concept to understand collusion dynamics beyond the conventional rational beliefs and MPE, applied to the Chilean pharmacy cartel case Alé Chilet (2016, 2018).

Movitation - Background

- Based on price-fixing case in Chile pharmacy retailing in 2006 - 2008.
  - 3 chains sell almost every purchase of drugs.
  - Different strategies across time.
  - Rebuild cooperation after change of ownership of Salcobrand(smallest chain).
- Gradual in collusion. Price Trend
  - Raise price on over 200 drugs during 5 months.
- Finding: evidence of **learning-to-coordinate**.

Price Leadership

Motivating Example - Coordination

- If rational: firms actions are explained by market characteristics.
- The two markets are not connected on demand/supply, write as separate decisions.
- Market outcome.
    - **Static competition**.
    - **Price leadership**.
- **Problem**: firms may be uncertain how other firms will respond.
- **Firms' learning**: firms update their beliefs given meta-game history.

Leader's Problem with Trust-Building

$$\tilde{v}_{im}(a_{imt} = 1, \mathbf{x}^{\text{Compete}}, h) = \underbrace{\left(1 + \beta(1 - \phi_m^{(1)})\right)\pi_{im}(\mathbf{x}_m^{\text{Lead}}) - \left(\text{MC}_{im}\right)}_{\text{Flow payoff during the period of leading}}$$

$$\underbrace{+\beta\left(\frac{\phi_m^{(1)}}{1-\beta}\underbrace{\left(\pi_{im}(\mathbf{x}_m^{\text{Collude}}) - \pi_{im}(\mathbf{x}_m^{\text{Compete}})\right)}_{\text{Profit Difference } z_{im}^{\text{Profit}}}\right) - \left(1 - \phi_m^{(1)} - \beta(1 - \phi_m^{(1)})\right)\frac{\pi_{im}(\mathbf{x}_m^{\text{Compete}})}{1-\beta}}_{\text{Future payoff difference if succesful collude}} \quad (1)$$

- $V(\mathbf{x}_m^{\text{Collude}})$ is represented as $\frac{1}{1-\beta}\pi_{im}(\mathbf{x}_m^{\text{Collude}})$. The price leader, firm i, has a single lead opportunity.
- Firm i's *belief* about firm i''s action, denoted as $\phi_m^{(1)}(h)$, increases with successful coordination (h).
- The incentive to lead, $p_{im}^{\text{Lead}} = \Lambda(\tilde{v}_{im}(a_{imt} = 1, \mathbf{x}^{\text{Compete}}, h))$, determines whether firm i will initiate a price increase.
  - As trust $(\phi_m^{(1)}(h))$ increases, so does the leader's incentive to lead due to increasing probability of future payoff and decreasing potential loss from failure.
  - Firms tend to lead in a market with a larger profit difference.

Motivating Example - Decision Rule

- Decision depend on payoff-relevant state variables(**?**) with relaxed belief.
- Strategy on market m:

$$\sigma_{im}(\underbrace{a_{im,t-1}, \quad a_{jm,t-1}, \quad \epsilon_{imt},}_{\text{Payoff related}} \quad \underbrace{h_t}_{\text{No payoff related}} \quad)$$

- h_t is a function of history, for example,
  - collusion on the other market;
  - whether other firms have deviated(Fershtman and Pakes (2000))
- **Diffusion of collusion**: If firms collude on Eranz, may collude on Folisanin.

Model

- ▷ Model under the **dynamic game** with **relaxed beliefs**.
  - ◇ demand side: simple logit
  - ◇ supply side: strategy interaction and belief evolution
- ▷ Issue: under-identification
- ▷ Restriction: each firms' belief about **other firms' action** is valued by a firm-specific time-varying **belief parameter**
  - ◇ between 0 and 1
    - ★ 1: rational belief under collusive strategy
    - ★ 0: competitive belief
  - ◇ evolve with signal of others firms' williness to collude

Dynamic Collusion and Counterfactual Experiments

Extending Collusion Models

- This study builds on Aguirregabiria and Magesan (2020), identifying beliefs as a key non-payoff relevant variable.
- Employing the Trust Building Equilibrium (TBE) framework, it reveals a gradual increase in firms' propensity to raise prices and promote collusion.
- In contrast, the standard MPE framework suggests immediate, uniform collusion, overlooking temporal incentives evolution.
- The TBE allows for a nuanced understanding of collusion dynamics.

Market Overview

- *Oligopolistic* retail pharmaceutical distribution market (Data Source: Expert report, court documents).
  - 92 % of the drugs sales are concentrated Farmacias Ahumada S.A. ("FASA"), Farmacias Cruz Verde S.A. ("Cruz Verde") and Farmacias Salcobrand S.A. ("Salcobrand").
  - 8 % independent drug stores that do not carry branded drugs.
- Prices not regulated.
- Physicians prescribe on brands.
- Insurance cover very limited, listed price reflects out-of-pocket price.

Data

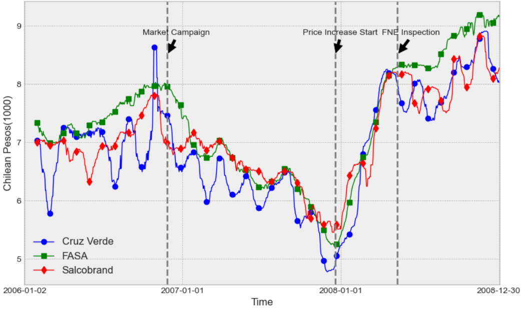
- Daily level data, from Jan 1st, 2006, to Dec 31st, 2008.
- 222 brands that the chains were accused of colluding.
- For each chain, each brand:
  - Nationwide sales volume (q_{imt});
  - Nationwide sale-weighted average price (p_{imt}) .
- Among the products:
  - Mostly are prescription drugs;
  - 70 % of the drugs are treatments for chronic diseases.
- Data source: Competition Tribunal of Chile.

Price Evolution

- January 2006 - December 2006: *Loss leadership*.
- December 2006 - August 2007: *Price war*.
- August 2007: Salcobrand 100% ownership sold to Juan Yarur Companies for 130 million dollars.
- November 2007 - April 2008: *Gradual Price increase*.
- April 2008: FNE investigation started.
- The Competition Tribunal sentence Farmacias Cruz Verde Salcobrand to pay fines of approximately US$19 million each.

Sentence Coordination Mechanism

Price Trend: Weighted Average Price Level from Jan 2006 - Dec 2008



Sentence Coordination Mechanism Background Price Leadership

Stylized Facts

1. Post-collusion: coordinations happen more frequently.
   ▸ Definition ▸ Coordinated Price Increase
2. The smallest chain, Salcobrand, is the **price leader**.
   ▸ Price Leader
3. First collude on more **differentiated** market.
4. The collusion on other markets without demand link increase firms' incentive to collude.
   ▸ Firms' Incentive ▸ Robustness Check

Dynamic Game: Identification of Belief

Define the associated conditional choice probabilities(CCPs)(Magnac and Thesmar (2002)):

$$\mathbf{P}_{imt}(a_{imt}, \mathbf{a}_{m,t-1}, \mathbf{h}_t) = \int \sigma_{im}(a_{imt}, \mathbf{a}_{m,t-1}, \mathbf{h}_t) d\epsilon_{imt}. \tag{2}$$

- Let h denote firms' collusion status on the other market.
- $\mathbf{P}_{imt}(a_{imt}, \mathbf{a}_{m,t-1}, \mathbf{h}_t) = \Lambda(\mathrm{v}_{it}^{\mathbf{B}_{it}}(a_{im}, \mathbf{a}_{m,t-1}, h_t))$,
  - $\Lambda(\cdot)$ is the CDF of ϵ_{imt},
  - $\mathrm{v}_{it}^{\mathbf{B}_{it}}(a_{im}, \mathbf{a}_{m,t-1}, h_t)$ choice dependent value function

Value Function CCP

- Identify a the **ratio of beliefs** from ratio of $\Lambda^{-1}(\mathbf{P}_{imt}(a_{imt}, \mathbf{a}_{m,t-1}, h))$ across h. (Aguirregabiria and Magesan (2020))

Dynamic Game: Flow Payoff

$$\Pi_i(\mathbf{x}_{mt}, \mathbf{a}_{mt}) = \sum_{m \in \mathcal{M}} \left[\mathrm{R}_{im}(\mathbf{x}_{mt}, \mathbf{a}_{mt}) + \mathrm{A}_{im}(\mathbf{x}_{mt}, \mathbf{a}_{mt}) + \epsilon_{imt}(a_{imt}) \right],$$

where

- $\mathrm{R}_{im}(\mathbf{x}_{mt}, \mathbf{a}_{mt})$: estimated profit, level of differentiation;
- A_{im} structural cost, unknown to economist;

$$\mathrm{MC}_{im} = \gamma_i^{\mathrm{MC,o}}, \ \mathrm{LC}_{im} = \gamma_i^{\mathrm{LC,o}} + \gamma_i^{\mathrm{LC,Profit}} z_{im}^{\mathrm{Profit}} + \gamma_i^{\mathrm{LC,Size}} \log(z_m^{\mathrm{Size}}), \tag{3}$$

  - Menu cost
  - Leadership cost
- $\epsilon_{imt}(a)$ i.i.d across players, markets, states and actions.(Magnac and Thesmar (2002))

Fixed Cost Specification

Dynamic Game: Overview

- Goal: Estimate **beliefs** $\mathbf{B}_{im}$, **profit** R_{im} and **structural cost** F_{im}.
- The dimensionality of the state is **huge($2^{(3*200)} \approx 4 * 10^{180}$).**
- Make the following restrictions:
  - The decision of prices is restricted to two price levels: low and high.
  - A market manager (i, m) makes a separate decision from other markets.
  - Beliefs are biased by a single firm-history-specific parameter $\lambda(h_t) \in [0, 1]$.
    - $\lambda(h_t) = 0$, players believe in static competition.
    - $\lambda(h_t) = 1$, players have rational belief in the leadership of prices.
  - h_t is number of colluded markets. $h_t \in \{[0, 30], [31, 90], [91, 150], [151, \infty)\}$.

History ▸ Price Leadership

Panel A: Estimation of Belief Parameters $\lambda(b)$

History	Estimates	Bootstrap
History 0-30	0.1789	0.153 (0.089)
History 30-90	0.2930	0.439 (0.271)
History 90-150	0.5182	0.515 (0.170)
History 150+	1.0000	-

Panel B: Estimation of Structural Costs (1000 Chilean Pesos)

	TBE			MPE		
Costs	Cruz Verde	FASA	Salcobrand	Cruz Verde	FASA	Salcobrand
Menu Cost	74.619	96.044	84.711	14.218	1334.256	107.641
Leadership Cost	1602.475	2238.598	1429.974	95804.489	323648.470	4.219
90% Quantile	3985.463	5265.212	3182.917	225968.155	727003.623	282.964
10% Quantile	79.059	164.346	59.532	10971.365	52475.795	227.776

Panel C: Estimation of Structural Costs Parameters

Panel C: Estimation of Structural Costs Parameters

	TBE			MPE		
Parameter	*Cruz Verde*	*FASA*	*Salcobrand*	*Cruz Verde*	*FASA*	*Salcobrand*
γ^{MC}, o_i	74.6188	96.0439	84.7112	14.2176	1334.2561	107.6409
	(22.8003)	(41.8131)	(38.0040)	(9155.2740)	(2250.9839)	(51.0140)
γ^{LC}, o_i	-213.2839	-242.7637	-218.2709	-5161.4021	-777.7465	-255.3117
	(62.9368)	(137.0481)	(72.3270)	(16489.2515)	(10772.5192)	(76.7080)
γ^{LC}, Size_i	0.0527	-0.5238	-0.4002	13.6036	-91.6494	-0.3254
	(0.8594)	(1.3888)	(0.7702)	(1189.9790)	(906.1534)	(0.4056)
γ^{LC}, Profit_i	8.9545	10.7311	9.1895	486.7926	1423.1862	1.6946
	(1.3819)	(4.2826)	(0.2825)	(1516.7731)	(1864.8742)	(0.8675)

Prediction of Firms' Price Leadership Probabilities

Table: Prediction of Firms' Price Leadership Probabilities

	Cruz Verde		FASA		Salcobrand	
	TBE	*MPE*	*TBE*	*MPE*	*TBE*	*MPE*
[0-30]	0.0104	0.0069	0.0155	0.0000	0.0316	0.6096
[30-90]	0.0451	0.0058	0.0846	0.0000	0.0375	0.5887
[90-150]	0.0484	0.0061	0.0104	0.0000	0.1101	0.6092
[150+]	0.2898	0.0058	0.2558	0.0000	0.4725	0.6742
All	0.0984	0.0062	0.0916	0.0000	0.1629	0.6204

[1] The table reports the mean probability of Salcobrand initiating a price increase affecting 204 products.
[2] Under MPE, the probability of FASA leading a price increase essentially hit 0 because I bind the probability of leading to be 1e-6.

Model Prediction - Simulated Path

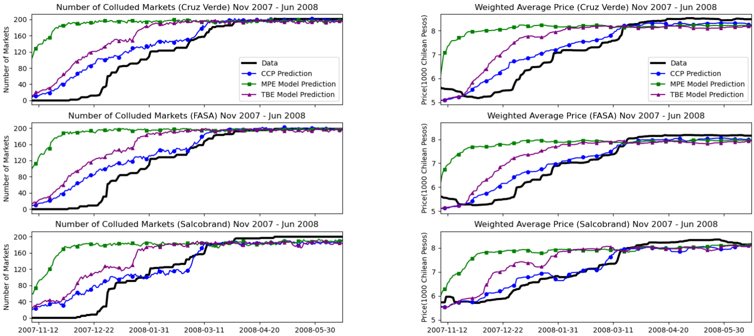


Figure: Model Prediction - Simulated Path

Dynamic Collusion and Counterfactual Experiments

Counterfactual Scenarios

- **Adjustment Friction Scenario:** Incorporates increased menu costs, leading to complex inter-firm dynamics and price adjustment hesitancy.
- **Divestiture Scenario:** Based on Harrington Jr (2018), it simulates a government-enforced 25% asset divestiture, resulting in a new competitor.

Mean Predicted Leader Probability in Counterfactual Experiment - Salcobrand

Table: Mean Predicted Leader Probability in Counterfactual Experiment - Salcobrand

	Trust Building Equilibrium			Markov Perfect Equilibrium		
	Model	Adjustment Friction	Divestiture	Model	Adjustment Friction	Divestiture
[0-30]	0.0316	0.0025 (-92.1619 %)	0.0029 (-90.9450%)	0.6096	0.3824 (-37.2706%)	0.4488 (-26.3775%)
[30-90]	0.0375	0.0048 (-87.3246%)	0.0030 (-92.1306%)	0.5887	0.2811 (-52.2456%)	0.4189 (-28.8447%)
[90-150]	0.1101	0.0132 (-88.0339%)	0.0055 (-94.9968%)	0.6092	0.3343 (-45.1228%)	0.4339 (-28.7686%)
[150+]	0.4725	0.1967 (-58.3724%)	0.0562 (-88.1068%)	0.6742	0.4953 (-26.5379%)	0.4462 (-33.8228%)
[All]	0.1629	0.0543 (-66.6871%)	0.0169 (-89.6400%)	0.6204	0.3733 (-39.8349%)	0.4370 (-29.5723%)

[1] This table presents the average probabilities of Salcobrand initiating price increases, encompassing 204 products.
[2] The second line details the percentage decrease in comparison to the model's prediction.

Contribution

- Introduces a dynamic game model for collusion initiation integrating 'higher-order knowledge'.
- Provides empirical evidence that successful collusion increases future collusion likelihood, changing expectations of collusive equilibrium adherence.
- First structural model for **collusion initiation** with **learning-to-coordinate**.
  - Finding: the gradualism in collusion explained by learning-to-coordinate.
  - Counterfactual: introduce more player to hinder coordination.
- First **biased-belief equilibrium** framework for dynamic game.
  - Counterfactual analysis.
  - Clear identification results.
  - Can test whether belief is biased.

Thank You

Thank You

Collusion News

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ECONOMY

'New Case of Collusion in Chilean Medicine Market'

by Boris van der Spek 20 January, 2020 0 1221

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Reading Time: 2 minutes

SANTIAGO – A recent investigation shows that the three major pharmacies in Chile are holding prices of at least 120 medicines artificially high. According to one of the journalists involved, the study shows that pharmacies are still colluding, over 10 years after a major collusion scandal struck the Chilean medicine market. The journalists in charge have handed the details to the National Prosecutor.

▶ Motivation

Definition of Expected Payoff

- Given current beliefs, we can represent a firm's best response at time t using solution from a single agent Dynamic Programming(DP) problem following Bellman's principle.

$$V_{it}^{B_{it}}(\mathbf{x}_t) = \max_{a_{it}}\{\pi_{it}^{B_{it}}(a_{it}, \mathbf{x}_t, \epsilon_{it}) + v_{it}^{B_{it}}(a_i, \mathbf{x}_t)\}$$

- The current epxected payoff

$$\pi_{it}^{B_{it}}(a_{it}, \mathbf{x}_t, \epsilon_{it}) = \sum_{\mathbf{a}_{-it}} B_{it}(\mathbf{a}_{-it}|\mathbf{x}_t)\Pi_{it}(a_{it}, \mathbf{a}_{-it}, \mathbf{x}_t, \epsilon_{it}).$$

- And the expected continuation value

$$v_{it}^{B_{it}}(a_i, \mathbf{x}_t) = \sum_{\mathbf{a}_{-it}} \beta B_{it}(\mathbf{a}_{-it}|\mathbf{x}_t) \sum_{\mathbf{x}_{t+1}} f(\mathbf{x}_{t+1}|a_{it}, \mathbf{a}_{-it}) V_{it+1}^{B_{it}}(\mathbf{x}_{t+1}).$$

Equilibrium Strategy

Competition Tribunal Sentence

- The Competition Tribunal sentence Farmacias Cruz Verde Salcobrand to pay approximately US$19 million each (Maximum applicable fine).
- Collusive agreement to increase prices of at least 206 pharmaceutical drugs between December 2007 and March 2008.
- The price in real values before vs. after the break it was 16.4% for SB, 18.6% for CV and of 16.9% for FASA.

Price Trend

Coordination Mechanism

Salcobrand's business manager emailed the CFO at the onset of the conspiracy period, on December 19, 2007, explaining the actions they were undertaking:

> *[In order to coordinate the price increases] we offered to be the chain that raised its prices first ([every week] on Monday or Tuesday) so that the other two chains would have three or four days to 'detect' these [price] increases and absorb them. Until now, [we have] succeeded in raising the prices of five of the most important products of four pharmaceuticals companies. Due to the good results, we hope to repeat the 'procedure' with more products and with more pharmaceuticals in the coming weeks.*

Price Trend

1-2-3 Price Increase

Define the coordinated price increase as:

1. The increase of price ($> 15\%$ or more than 1500 peso) is happened for a certain product for 3 firms.
2. The increase is started by one firm, and the other two firms follow within at most 4 days.
3. The price levels before and after increases should be reasonably close($< 15\%$).
4. The price level is maintained for at least 3 days.

Number of coordinated price increase | Facts

Coordinated Price Increase

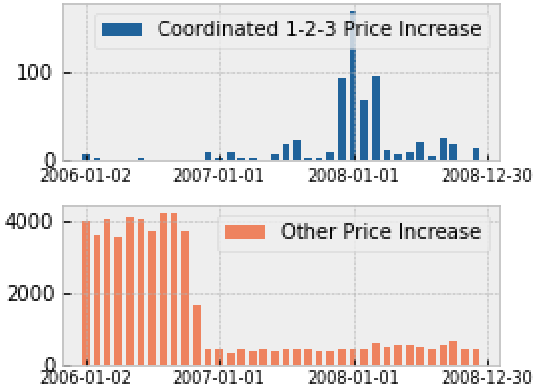

Figure: Number of Coordinated Price Increase

Facts

Table: The Coordinated Price Increase Frequency

Time periods	Frequency	Percentage	Monthly average
Jan,2006 - Nov, 2007	24	12.8%	1.04
Dec,2007 - Apr, 2008	137	72.9%	27.40
May,2008 - Dec, 2008	27	14.4%	$\boxed{3.86}$
Total	188	100%	5.22

[1] The coordinated price increase is defined by the action such that one firm make a price increase on a certain product, and the other firms follow within a reasonable short time period.

[2] The table recomputed using the method in the expert report requested by FNE. ?.

Definition of coordinated price increase Facts

Table: The 1-2-3 Price Increase/ Decrease Frequency

Sequence	Jan,2006 -Nov,2007	Dec,2007 -Apr,2008	May,2008 -Dec,2008	Total
	1-2-3 Price Increase			
SB lead	11	$\boxed{126}$	10	147
FA lead	12	8	10	30
CV lead	10	0	12	31
Total	32	$\boxed{143}$	32	188

[1] The table is recomputed according to the method reported in the expert report **?**

[2] Based on the foregoing, the relevance of SB on the subject is highlighted, because of the total increases 1-2-3 accounted for, 75% of them (162 increases) are made in the first movement.

▸ Definition of coordinated price increase ▸ Facts

Time Varying Incentive

Estimate a Cox survival(Cox, 1972) model following that of Alé Chilet (2016).

- A market is defined as a product j, where three firms compete on.
- A failure is defined as the market starting to collude.
- Explainatory variables
  - History is the number of drugs that firms have already colluded on.
  - The elasticity is estimated in the first stage with logit demand model.
  - Market size is the daily average quantity sold by three firms before collusion(Oct, 2007).
  - Price dispersion is the average weekly price standard deviation(Jan, 2006 - Oct, 2007).
  - Share dispersion: the median of weekly share dispersion. Reflects the asymmetry of the firms' shares.

Facts

Table: Timing of Collusion: Market Characteristics

	Proportional Hazard Model			Time-varying Hazard Model			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Cross Elasticity	-0.354	-0.351	-0.3427	-1.0608	-1.5021	-1.3806	-1.3781
	(0.2572)	(0.2481)	(0.2469)	(6.117)	(6.6812)	(6.4657)	(6.4683)
Ln Market Size	0.4516***	0.4538***	0.4536***	1.2521	1.1596	1.4032	1.4059
	(0.0771)	(0.133)	(0.1319)	(2.3947)	(2.3576)	(2.719)	(2.7302)
Succeed Ratio	-	-	0.9193***	-	0.0003	-	0.0109
	-	-	(0.0871)	-	(0.0896)	-	(0.0872)
Total Coord Attemp	-	-	-0.0084***	-	-0.0002	-	0.0002
	-	-	(0.0021)	-	(0.002)	-	(0.0021)
Cross Elasticity * $\log(T)$	-	-	-	0.2045	0.2972	0.2737	0.2732
	-	-	-	(1.2488)	(1.3736)	(1.3288)	(1.3293)
Ln Market Size * $\log(T)$	-	-	-	-0.2472	-0.2267	-0.2785	-0.2791
	-	-	-	(0.4859)	(0.4743)	(0.5514)	(0.5539)
Price Dispersion	-	0.1195	0.118	-	-0.2415	-0.1784	-0.1763
	-	(0.1169)	(0.1189)	-	(1.3415)	(1.3273)	(1.3239)
Share Dispersion	-	-0.3425	-0.2112	-	7.3582	12.4508	12.4217
	-	(3.3214)	(3.3091)	-	(19.5943)	(22.4463)	(22.4248)
Price Dispersion * $\log(T)$	-	-	-	-	0.05	0.0368	0.0363
	-	-	-	-	(0.2824)	(0.2801)	(0.2794)
Share Dispersion * $\log(T)$	-	-	-	-	-1.4203	-2.4906	-2.4843
	-	-	-	-	(4.1841)	(4.7433)	(4.7401)
Market Share Leader	-	-4.7582***	-4.5848**	-	-	-7.8503	-7.9218
	-	(1.8229)	(1.8172)	-	-	(18.6303)	(18.7535)
Market Share Leader * $\log(T)$	-	-	-	-	-	1.6039	1.6193
	-	-	-	-	-	(3.9032)	(3.9316)
AIC	70949.5716	70206.827	70060.37	69750.8864	69668.6737	69534.101	69537.028
Concordance Index	0.5088	0.4912	0.548	0.9749	0.9569	0.9749	0.9567
N	22398	22376	21984	22398	21984	22376	21984
log-likelihood	-35472.7858	-35098.4135	-35023.185	-34871.4432	-34824.3368	-34757.0505	-34756.514

Dynamic Game: Value Function

- *Choice dependent value function*: $\mathrm{v}_{it}^{\mathbf{B}_{it}}(a_{im}, \mathbf{x}_t) =$
  $\mathbb{E}_{\mathbf{B}_{it}}\left[\pi_{im}(a_{imt}, \boldsymbol{a}_{-im}, \boldsymbol{x}_{mt}) + \beta f(\boldsymbol{x}_{j,t+1}|\boldsymbol{a}_{mt}, \boldsymbol{x}_{mt})\mathbf{V}_{im}(\boldsymbol{x}_{j,t+1})\right],$
- *Value function*:
  $\mathbf{V}_{im}(\boldsymbol{x}_{jt+1}) = \max_{a_{im}}\{\mathrm{v}_{it}^{\mathbf{B}_{it}}(a_i, \mathbf{x}_t) + \sum_{m\in\{Folisanin,Eranz\}} \epsilon_{imt}(a_{imt})\}.$

Dynamic Game Best Response

Dynamic Game Identification

? propse the following assumptions to identify markov perfect equilibrium dynamic game.

Assumption (Identification of MPE Dynamic Game)

1. a_{it}, x_{it} *have finite supports.*
2. $\epsilon_{it}(a_i)$ *is additive seperable.*
3. ϵ_{it} *is conditionally independent of* $\mathbf{x}_t | \mathbf{x}_{t-1}$.
4. *Firms' private information* $(\epsilon_{1t}, \ldots, \epsilon_{Nt})$ *are drawn from* $T1EV$ *distribution* $G_i(\cdot)$, ϵ_{it}*'s are independently distributed over time.*

▸ Dynamic Game Best Response

Assumption: Exclusion Restrictions

Assumption (Exclusion Restriction)

The vector of state variables $\mathbf{x}_{mt}, h_t$ *satisfy the following conditions:*
(A) $\pi_{im}(\boldsymbol{a}_{mt}, \boldsymbol{x}_{mt}, h_t) = \pi_{im}(\boldsymbol{a}_{mt}, \boldsymbol{x}_{mt})$,
(B) $\pi_{im}(a_{imt}, a_{-imt}, x_{imt}, x_{-imt}, h_t) = \pi_{im}(a_{imt}, a_{-imt}, x_{imt}, x'_{-imt}, h_t)$,
(C) $f(\mathbf{x}_{m,t+1}|(a_{imt}, a_{-im}), \mathbf{x}_{mt}) = \Pi_{i\in\mathcal{I}} f(\mathbf{x}_{im,t+1}|a_{imt})$. ■

Dynamic Game Best Response

Table: Average Quantity Level Before and After the Price Increase

	Before	After
All drugs	215.5	200.3
By Prescription		
Prescription Drugs	214.4	201.2
Over-the-Counter Drugs	221.0	195.5
By Chronic Disease		
Chronic Disease	165.8	154.0
Non-Chronic Disease	308.1	286.1

[1] For each drug, I compute the average daily sale from 14 days to 7 days before the price increase, and 7 days to 14 days after the price increase.
[2] The daily average were computed using the Dec 2007 - Apr 2008 period.

Dynamic Game Estimation

Consumer Demand Model

Market defined as each brand. Consumers are homogeneous, market size is fixed. Each t, the consumer on the market choose to buy from a firm i. For each consumer who buys drug j, firm i at time t, the utility is

$$u_{imt} = \beta_m - \alpha_m p_{imt} + \xi_{mt}^{(1)} + \xi_{imt}^{(2)}, \tag{4}$$

- β_m is the utility parameter,α_j is the *price paramters*,
- $\xi_{mt}^{(1)}$ is the firm-product fixed effect, and $\xi_{imt}^{(2)}$ is the time-varying demand shock.
- $\xi_{imt}^{(2)}$ follows AR(1) process: $\xi_{imt}^{(2)} = \rho_m \xi_{im,t-1}^{(2)} + \epsilon_{imt}$.
- ϵ_{imt} i.i.d across i, m, t.

Parameters: $\{\beta_m, \alpha_m, \rho_m, (\xi_{mt}^{(1)})_{i \in \mathcal{I}}\}_{m \in \mathcal{M}}$ Dynamic Game Estimation

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