THE UNIVERSITY OF WARWICK

Department of Economics

EC331: Research in Applied Economics

Game Theory Behind the Reasons for the Enforcement and Breakdown of Collusive Agreements

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Abstract

The Great Global Vitamin Conspiracy or "The Mother of All Global Cartels" has been the subject of a vast empirical analysis on the standard factors, affecting the sustainability of collusive agreements. It, however, allows for the evaluation of aspects of collusive behaviour beyond the scope of traditional analysis. One of them is the existence of multi-market contact. Do firms treat all cartels they participate in, individually or altogether, and how does this affect the sustainability of collusive agreements? This is the subject of this project.

Contents

1 Introduction

The Great Global Vitamins Conspiracy is the biggest, most elaborate, longest lasting and most harmful of the international cartels of the late 20th century. In the late eighties 21 chemical manufacturers joined 16 cartels, each one operating in the market for a distinct bulk vitamin. Major Players were the Big Three, controlling 60% of the world production. Hoffmann -La Roche - the industry leader, organised 14 out of the 16 cartels, with BASF and Takeda as its main partners in crime. The 16 cartels ended in one of 2 ways - 6 of them fell apart in 94/95, the other 10 were forcibly terminated in 98/99 by US government investigations.

The Vitamin Conspiracy is the best documented case of collusive agreements for the past 20 years. It therefore represents a perfect real-world laboratory for theoretical analysis of firms' incentive compatibility, necessary for the self- enforcement of any cooperation.This project focuses on examining the cartels for vitamins C,B1,B2,B6 and B9, which shared relatively similar characteristics. The vitamin C and B2 cartels existed officially from 01/1991 to mid 1995, the other three - from 01/1991 to 06/1994. For the period of their existence, all five cartels faced similar demand growth and fringe supply increase.

The main aim of the project is to elaborate on the internal correlations between simultaneously operating cartels with the same major participants by evaluating the effect of multi-market contact. It also examines the impact of firms' capacity constrains and discount factors on the sustainability of collusive agreements.

The project consists of two parts. The first one presents the theoretical model I have developed, which incorporates the concrete market characteristics and historical behaviour of the vitamin industries. The second part contains the empirical analysis of the results, obtained after running simulations, based on the model. It elaborates on the numerous factors, determining firms' collusive behaviour and provides alternative explanations for the simultaneous breakdown of all five cartels. Central focus of this analysis is the multi-market contact.

2 Literature Review

The nature of collusive agreements has been the subject of a vast amount of research for the past sixty years.The relevant literature review naturally starts with George Stigler (1964)[9], who developed a theoretical model, accounting for the conditions governing the feasibility of collusions. Detecting secret price-cuttings is what he identifies as the greatest obstacle for a collusion in an industry environment, immune to entry.

The detection of deviations is naturally followed by punishment. Ian Ayres (1987)[2] emphasizes the necessity of credible punishment in order for a collusive agreement to be self-enforcing. He examines a wide range of punishment strategies, affecting the demand or supply, facing the defecting firm, and points out that the punishment pricing is the most direct way to reduce the defecting firms future profits. However, it also reduces severely the punisher's profits, which considerably weakens its credibility.

The controversy arising from the punishment pricing has been central for numerous papers. The first attempts to formalize the idea of price wars (Rubinstein (1979)[8], Abreu (1986)[1]) indicate that this threat is off the equilibrium path, unless we allow for demand uncertainty and asymmetric information(Green and Porter (1984)[6]).

These conclusions clearly indicate the effect of incorporating more realistic assumptions. Fershtman and Pakes (2000)[5] develop a dynamic model, accounting for firms heterogeneity, investment, entry and exit decisions. Nicolas de Roos (2004)[4] adjusts their model's sensitivity to informational asymmetries with regard to new entrants. His main result states that joining a cartel is beneficial only after the new entrant has gained relatively significant market shares.

The last, but most relevant paper to this project is the one by Igami and Sugaya (2016)[7]. It provides a theoretical measurement of the incentive to collude in the context of the Great Global Vitamin Conspiracy. Their paper focuses on the vitamin C cartel and claims that the unexpected expansion of the fringe supply in the years before 1995 is the main reason for its collapse.
They also suggest a relatively weak correlation between the cartels, therefore, they examine each vitamin industry in isolation.

However, there are numerous factors, suggesting the existence of multi-market contact, which have to be considered. Namely this is the main aim of this project.

3 Theoretical Model

3.1 Key assumptions

1. The model examines three market regimes: Collusion, Deviation, and Punishment (static Cournot-Nash Equilibrium);

2. Number of cartel members - $\boldsymbol{I}$.

3. All firms compete in quantity (Cournot Competition).

4. The Demand function is as follows:

$$Q_t = \frac{dQ}{dP}P_t - Q_{fri,t} + X_t \tag{3.1}$$

The Market Price is determined by the following formula:

$$P_t = \frac{dP}{dQ}(Q_t + Q_{fri,t} - X_t), \tag{3.2}$$

where Q_t is the supply by the cartel members,
$\frac{dP}{dQ}$ (α for simplicity) is the slope of the inverse demand curve,
X_t is the demand shifter in period t,
$Q_{fri,t}$ is the fringe supply in period t(treated as exogenous).

5. The total supply of vitamins in the market is given by:

$$Q_t^{Total\ Supply} = Q_t + Qfri,t, \tag{3.3}$$

6. Time length of t - one month;

7. Costs:
All firms have the same cost of production, constant in time. This reflects the fact that every vitamin industry has already reached a mature level of development and all firms have equalized their methods of production:

$$c_{i,t} = \overline{c}, i = 1, ..., \boldsymbol{I}, t = 1, 2, ... \tag{3.4}$$

8. Market Shares $s_{i,t}$:
Every cartel determines its quota settings on the basis of its members' global production shares. Each firm's production quota in year τ is determined by its global production share in year $\tau - 1$:

9. Expectations:
Firms form **static expectations** for market's demand and fringe supply:

$$(\frac{dP}{dQ})^{exp}_{t+\tau} = (\frac{dP}{dQ})_t, \tau = 1, 2, ... \tag{3.5}$$

$$X^{exp}_{t+\tau} = X_t, \tau = 1, 2, ... \tag{3.6}$$

$$Q^{exp}_{fri,t+\boldsymbol{\tau}} = Q_{fri,\boldsymbol{\tau}}\ t = 1, 2, ... \tag{3.7}$$

Static expectations for the demand and fringe supply result in **static expectations** for firms' global market shares:

$$s^{exp}_{i,t+\boldsymbol{\tau}} = s_{i,\boldsymbol{\tau}}\ t = 1, 2, ... \tag{3.8}$$

Note: The assumption we made about firms' expectations completely correspond to the information, collected and documented during the prosecution of the vitamin cartels, which started in 1999. [3].

10. Estimations:
Firms make correct estimations of α_t and X_t for every t. Their estimation of the fringe supply is:

$$Q^{estimate}_{fri,t} = Q^{real}_{fri,t} \; for \; t = March, June, Sep, Dec \tag{3.9}$$

$$Q^{estimate}_{fri,t+\tau} = Q^{real}_{fri,t} \; for \tau = 1, 2 \tag{3.10}$$

$$\tag{3.11}$$

11. Monitoring and Information Transmission:
Each vitamin cartel exhibited almost perfect monitoring.The historical records state that their management structure was extremely elaborate. Meetings of the chiefs of global vitamins marketing have been organised on a quarterly basis, when third party supplemented the quarterly exchange of internal sales records. This implies that detection of deviations from the collusive agreement occurred after 3 months at the latest, i.e. the optimal duration of the Deviation regime is 3 months.

12. Capacity Constraints:
In the absence of capacity constraints in the Punishment regime all firms would have produced the same optimal quantity due to their identical MC. However, this is not the case in the Great Global Vitamin Conspiracy, which suggests the central role of capacity constraints. In section 5 we discuss the outcome of implementing different capacity constraints in Deviation/Punishment regimes.

3.2 Collusion Mode

In this regime each cartel maximises its joint profits by choosing an optimal production level:

$$Q^C_t = \frac{c + \alpha X_t - \alpha Q^{exp}_{fri,t}}{2\alpha} \tag{3.12}$$

$$\tag{3.13}$$

Every member is assigned a production quota, proportional to its intra-cartel market share:

$$q^C_{i,t} = s_{i,t} Q^C_t \tag{3.14}$$

After choosing the optimal output level, each cartel sets the corresponding market price P^C_t:

$$P^C_t = \frac{c + \alpha Q^{exp}_{fri,t} - \alpha X_t}{2} \tag{3.15}$$

Each firm expects to make profit $\pi^C_{i,t}$:

$$\pi^C_{i,t} = \frac{-s_{i,t}}{\alpha}\left(\frac{c + \alpha X_t - \alpha Q^{exp}_{fri,t}}{2}\right)^2 \tag{3.16}$$

Because of its static expectations about the market demand and fringe supply, it expects to make the same profits in the future.

3.3 Deviation Mode

The optimal duration of this regime is 3 months. Suppose that one firm decides to deviate from the collusive agreement by choosing a profit maximising output level, given the fringe supply and the production of the rest of the cartel:

$$Q^D_{-i,t} = (1 - s_{i,t})Q^C_t \tag{3.17}$$

Once it calculates its optimal production $q^D_{i,t}$, the defecting firm secretly cuts the price to $P^D_{i,t}$ and expects profit $\pi^D_{i,t}$:

$$q^D_{i,t} = \left(\frac{1 + s_i}{2}\right)\left(\frac{c + \alpha X_t - \alpha Q^{exp}_{fri,t}}{2\alpha}\right) \tag{3.18}$$

$$P^D_{i,t} = \frac{\alpha Q^{exp}_{fri,t} + c - \alpha X_t}{2} + \frac{\alpha(1 - s_i)}{2}\left(\frac{c + \alpha X_t - \alpha Q^{exp}_{fri,t}}{2\alpha}\right) \tag{3.19}$$

$$\pi^D_{i,t} = -\left(\frac{1 + s_{i,t}}{2}\right)^2\left(\frac{1}{\alpha}\right)\left(\frac{c + \alpha X_t - \alpha Q^{exp}_{fri,t}}{2}\right)^2 \tag{3.20}$$

Note that these formulae hold in the absence of capacity constraints or when they exceed the optimal output level $q^D_{i,t}$.
Otherwise, firm i aims at selling $K_{i,t}$. It therefore sets the price to:

$$P^D_{i,t} = \alpha(K_{i,t} + (1 - s_{i,t})Q^C_t + Q^{est}_{fri} - X_t) \tag{3.21}$$

3.4 Punishment Mode - Static Nash Equilibrium

Once deviation is detected, the cartel breaks down and the market reverses to an infinite repetition of the static NE. In this regime we implement Capacity constraints for each firm.

In order to find the Nash Equilibrium in the case of firms with different capacity constraints but equal cost of production, we proceed in the following way:
Without loss of generality, assume that $K_1 < K_2 <$ ...$< K_I$.

In the absence of capacity constraints, all firms would produce $q_{1,t}^N$:

$$q_{1,t}^N = \frac{\bar{c} + \alpha X_t - \alpha Q_{fri,t}^{exp}}{\alpha(I+1)} \tag{3.22}$$

Begin with the smallest firm. If $K_1 > q_{1,t}^N$, then all firms produce $q_{1,t}^N$, the market price is P_t^N and firms' expected profit is $\pi_{1,t}^N$:

$$P_t^N = \alpha(Iq_{1,t}^N + Q_{fri,t}^{exp} - X_t) \tag{3.23}$$

$$\pi_{i,t}^N = (P_t^N - \bar{c})q_{1,t}^N \tag{3.24}$$

If however, K_1 is less than $q_{1,t}^N$, firm 1 produces K_1.We define $q_{2,t}^N$ - the optimal production level for the other firms in the absence of capacity constraints.

$$q_{2,t}^N = \frac{c + \alpha X_t - \alpha Q_{fri,t}^{exp} - \alpha K_1}{\alpha I} \tag{3.25}$$

We check for the second smallest firm. If K_2 exceeds it, then all firms other than the first produce $q_{2,t}^N$, the market price is P_t^N:

$$P_t^N = \alpha((I-1)q_{2,t}^N + K_1 + Q_{fri,t}^{exp} - X_t) \tag{3.26}$$

and all firms' corresponding expected profits are:

$$\pi_{1,t}^N = (P_t^N - \bar{c})K_1 \tag{3.27}$$

$$\pi_{i,t}^N = (P_t^N - \bar{c})q_{2,t}^N \ i = 2, 3, ..., I \tag{3.28}$$

If K_2 is less than $q_{2,t}^N$, firm 2 produces K_2 and we proceed in the same way until we have checked for all I firms.

3.5 Incentive Constraints

Once we have derived firms' expected profits in all three market regimes, we're left to check for their incentive to collude. Collusion is sustained if for each firm the present discounted value of profits under collusion exceeds the present discounted value of profits after deviation and punishment. Mathematically, this idea is captured by the first formula (case when deviation is of maximum duration - 3 months):

$$\pi_{i,1}^C + \delta\pi_{i,2}^C + \delta^2\pi_{i,3}^C + ... \geq (\pi_{i,1}^D + \delta\pi_{i,2}^D + \delta^2\pi_{i,3}^D) + (\delta^3\pi_{i,4}^N + \delta^4\pi_{i,5}^N + ...)\ , for\ i = 1, 2, ..., \boldsymbol{I} \tag{3.29}$$

Static expectations about the fringe supply and market demand result in static expectations of firms' future profits in all three regimes. This helps us simplify the Incentive

Constraint:

$$\pi_{i,t}^{C}\sum_{j=0}^{\infty}\delta^{j} \geq \pi_{i,t}^{D}(1+\delta+\delta^{2})+\delta^{3}\pi_{i,t}^{N}\sum_{j=0}^{\infty}\delta^{j} \tag{3.30}$$

In order to test for the effect of multi-market contact on collusions' stability, the last thing to do is to combine firm i's Incentive Constraints for all M markets it operates in. This is captured by the last formula:

$$\sum_{m=1}^{M}\pi_{i,t}^{C,m}\sum_{j=0}^{\infty}(\delta_m)^{j} \geq \sum_{m=1}^{M}\pi_{i,t}^{D,m}(1+\delta_m+(\delta_m)^{2})+\sum_{m=1}^{M}(\delta_m)^{3}\pi_{i,t}^{N,m}\sum_{j=0}^{\infty}(\delta_m)^{j} \tag{3.31}$$

4 Data - Calibration of Theoretical Model

We next move on to the empirical part of the project. For the purpose of analysing the reasons behind the enforcement and breakdown of the five cartels of interest, I have run simulations, based on the theoretical model, which incorporate different assumptions about firms' capacity constraints and discount factors. The available initial data for each cartel was, however, extremely limited, and comprised of:

- Each firm's global market share for years 1990-1995;
- The market price of the good (€/kg) at the end of each year for years 1990-1995;
- The amount of global production at the end of 1990 (prior to collusion);
- The global production share of the fringe supply for years 1990-1995;

I have used this information and the theoretical model to estimate the values for the four main variables at the end of each year - the slope of the inverse demand curve α, the demand shifter X_t, the marginal cost c_t and the amount of real fringe supply $Q_{fri,t}^{real}$, after which I have recreated the missing monthly values for these variables. (Further explanation of the method of calibrating the model and the restored data - Appendix 8.1)

5 Simulations - Results

In this section we discuss the results from the simulations, based on the theoretical model. The first two simulations (extreme cases 1 and 2) provide evidence for the impact of capacity constraints on cartel members' punishment power and test for the need of their implementation in the Deviation regime. The third simulation incorporates more realistic assumptions and allows for evaluating the importance of the discount factor. It provides two possible scenarios, explaining the simultaneous breakdown of the cartels when:

1. they operate in isolation;
2. they are interconnected;

Last but not least, we shall discuss the effect of multi-market contact and the impact of the discount factors on the sustainability and simultaneous breakdown of the cartels.

5.1 Extreme Case 1 - $K_{i,t} = q_{i,t}^{collusion}$ in Punishment Regime, no Capacity Constraints in Deviation Regime

This scenario evaluates firms' incentive to collude when:

- No firm has capacity constraints in Deviation Regime;
- All firms have capacity constraints in Punishment Regime and $K_{i,t} = q_{i,t}^{Collusion}$;

Results and Observations: In the case of undetected "secret" price reduction and limitless production capacity in regime Deviation, firms make considerable profits. According to both the theoretical model and the simulation, the smaller the firm is in terms of intra-cartel market shares, the greater the difference $\Pi_{i,t}^{D}$ - $\Pi_{i,t}^{Collusion}$ and so the greater its incentive to defect. (Appendix 8.2)

When firms have capacity constraints $K_{i,t} = q_{i,t}^{Collusion}$ in the Punishment Regime, they produce and earn just as much as under Collusion. This implies that under the assumptions of this case no firm has any power to punish the defecting firm by increasing its production and so lowering the market price!

These two observations imply that every firm benefits considerably from cheating, however, its profits under collusion and competition are equal. Therefore, even if a collusive agreement has been reached, every cartel member will have an incentive to deviate from it at any moment in time!

Conclusion: This scenario is inconsistent with the historical events!

5.2 Extreme Case 2 - $K_{i,t} = q_{i,t}^{collusion}$ in Punishment Regime for all firms except for Roche, no Capacity Constraints in Deviation Regime

This scenario evaluates firms' incentive to collude, given that:

- No firm has capacity constraints in Deviation Regime;
- All firms other than Roche have capacity constraints in Punishment Regime and $K_{i,t} = q_{i,t}^{Collusion}$;
- Roche faces no capacity constraints;

Results and Observations: The only difference between this and the previous case is the assumption that the industry leader - Roche, faces no capacity constraints in regime Punishment. Intuitively this means that we assign all the punishment power to the biggest company. The other companies are incapable of imposing any threat on their rivals, for they cannot reduce the defector's profits in Punishment Regime by increasing their own production.
On one hand, Roche has enough punishment power to make its partners unwilling to deviate. For a certain discount factor, all other cartel members will have an incentive to comply with the agreement. On the other hand, Roche cannot be punished by its partners, because of their capacity constraints. In this case Roche's profits in Deviation and in Punishment Regimes are identical and are much higher than the profits under Collusion. This means that Roche will never have an incentive to collude, never mind organising all 5 cartels!

Conclusion: This scenario is inconsistent with the historical events!

5.3 New Assumptions

The extreme cases, considered above, indicate the need of more realistic assumptions, whose absence explains the discrepancy between the outcome of the first 2 simulations and the historical events.

1. **Production in Deviation Regime is limited by capacity constraints!**
   The theoretical model does not clearly indicate the need for this, however, once we have calibrated it, we see the numerical evidence for this. Even though this regime lasts for only 3 months, its effect on each firm's incentive constraint is immense.

2. **Capacity Constraints should be different from each firm's production quota under collusion $q_{i,t}^C$!**
   We shall examine different cases, in which $K_{i,t} = (1 + x\%)q_{i,t}^C$ This assumption incorporates the realistic view that each company has accumulated inventories, which can be used in case of positive demand shocks. It also provides each cartel member with punishment power, proportional to its size.

The next simulations verify the positive effect of these assumptions on firms' incentive to collude. Companies are no longer able to make exceptionally high profits by defecting and Roche is no longer possessing all the punishment power. In case of defecting, it now faces the credible threat of being punished by its cartel partners. Intuitively, these assumptions redistribute the punishment power to firms proportionally to their size and so increase their attractiveness as cartel partners.

5.4 Case 3 - each cartel member faces $K_{i,t} = 1.3q_{i,t}^{Collusion}$ in both Deviation and Punishment Regimes

The results obtained after adjusting the capacity constraints differ substantially from the results in the extreme cases. The new assumptions facilitate the enforcement and sustainability of all 5 collusions, introduce the role of each company's discount factor and thus allow for further analysis of their behaviour.
In what follows I shall discuss the observations from the simulations when each firm faces capacity constraint 30% higher than its production quota under collusion.

5.4.1 Firms' behaviour

Once we have adjusted the capacity constraints, the sustainability of the collusive agreements depends entirely on each member's discount factor. When firms discount their future by $\delta = 0.6$ or 0.7, no one has an incentive to cooperate (section 5.4.2). However, our theoretical model allows us to calculate each company's individual discount factor, for which its Incentive Constraint equals zero 3 months before the breakdown of the cartel it participates in(3 months before each cartel's collapse is the most critical moment in time).
Note that the cartels for vitamins C and B2 exist officially until 06/1995, whereas the other 3 - until mid 1994. However, there is evidence that the first two cartels became dis-functional about one year earlier. Therefore, for the purpose of this analysis, we assume that 03/1994 is the critical moment in time for all 5 cartels.
The cartel members are divided into two groups:

- Participants in 1 cartel: Merck(C), Rhone(B2), Daiichi(B6), Sumika(B9), Kong(B9);
- Participants in more than 1 cartel: Roche(all 5 cartels), Takeda(all 5 cartels), BASF(C,B1,B2);

The next table shows Group 1 members':

- discount factors for which their IC=0 in March 1994;
- collusive behaviour for this δ before 03/1994 and thus shows whether this company could have been the reason for the breakdown of its cartel;
- threshold for δ after which their IC is positive;

Table 5.1: Participants in only one cartel - discount factor analysis

Capacity Constraint = 1.3* Intra-Cartel Production Quota								
Company:	Cartel:	Discount factor for which IC=0 in 03/1994	Company's behaviour before 03/1994	Could this company have been the reason for the cartel's breakdown in 06/1994?	Discount factor for which IC=0 in 03/1995	Company's behaviour before 03/1995	Could this company have been the reason for the cartel's breakdown in 06/1995?	Discount factor threshold, after which IC is +ve
Merck	vitamin C	0.906091	Positive IC up to 03/1993, after that negative in every 3 months	NO	0.905623	Positive IC up to 03/1993, after that negative in every 3 months	NO	0.906091
Rhone	vitamin B2	0.939608	Positive IC up to 03/1994	YES	0.906454	Negative IC in every 3 months after 03/1994	NO	0.939608
Daiichi	vitamin B6	0.896667	Negative IC in every 3 months after 03/1991	NO				0.8979
Sumika	vitamin B9	0.896949	Positive IC up to March 1994	YES				0.896949
Kongo	vitamin B9	0.902162	Positive IC up to March 1994	YES				0.902162

By controlling for each firm's IC=0 in March 1994, we can test for its collusive behaviour up to this date. According to this analysis, many companies exhibit problematic behaviour before 03/1994, i.e. for this δ their Incentive Constraint becomes negative earlier in time.
If firm i exhibits problematic behaviour, then there does not exist a discount factor δ^*, such that $IC_t^i > 0$ before 03/1994 and $IC_t^i = 0$ in 03/1994. Intuitively, this means that these companies' critical moment in time was not 3 months before the breakdown of the cartel, hence, their real discount factor must have yielded positive IC throughout the whole life-span of the cartel.

Same table for Group 2 members you can find in the Appendix, Section 8.3.
Once we allow every company to have a different discount factor for every cartel it operates in, there exist numerous scenarios, explaining the collapse of the agreements.(Appendix 8.3.1)
It is, however, rational to assume that the major participants - Roche, Takeda and BASF, used the same discount factor in all markets they operated in. Intuitively, this implies that their δ is entirely determined by the company's intrinsic characteristics(market power, size, managerial team, etc) and is independent of the industry.

The next table gives information about these firms' Incentive Constraints for their critical discount factors (all δ-s for which their IC=0 for some cartel or their combined IC=0 in 03/1994):

Table 5.2: Major players - sign of IC before 03/1994

Roche - IC analysis for different discount factors						
Discount factor	C	B1	B2	B6	B9	Combined
0.686616	negative	negative	negative	negative	negative	negative
0.809483	positive	negative	positive	negative	negative	Positive until 03/1994
0.810481	positive until 03/1994	negative	positive	positive	negative	Positive
0.818573	positive	negative	positive until 03/1994	positive	negative	Positive
0.836160	positive	negative IC	positive	positive	negative	Positive
0.844088	positive	positive	positive	positive	negative	Positive
0.892000	positive	positive	positive	positive	positive	Positive
Takeda- IC analysis for different discount factors						
Discount factor	C	B1	B2	B6	B9	Combined
0.841627	negative	negative	negative	negative	negative	negative
0.873159	negative	positive	negative	negative	negative	negative
0.877757	positive	positive	negative	negative	negative	negative
0.879848	positive	positive	negative	negative	negative	positive
0.894406	positive	positive	negative	negative	positive	positive
0.896667	positive	positive	negative	negative	positive	positive
0.920000	positive	positive	positive	positive	positive	positive
BASF- IC analysis for different discount factors						
Discount factor	C	B1	B2	B6	B9	Combined
0.866872	negative	positive	negative	-	-	Positive until 03/1994
0.875178	negative	positive	positive until 03/1994	-	-	positive
0.907678	negative	positive	positive	-	-	positive
0.910000	positive	positive	positive	-	-	positive

5.4.2 The Role of the Discount Factor

The analysis of firms' collusive behaviour indicates the central role of the discount factor. Despite reducing the profits after deviation by introducing adjusted capacity constraints, the sustainability of cartel is impossible, when firms discount their future considerably (e.g δ=0.6 or 0.7).This implies that the new realistic assumptions are necessary but not sufficient for the cartels' sustainability.

Another central observation is the correlation **firm's size - discount factor for which its IC is positive for the whole period 1991-1994**. Smaller firms tend to start exhibiting unproblematic collusive behaviour for higher δ-s when compared to bigger companies. There are many explanations for this, which are discussed in the Appendix(8.4).

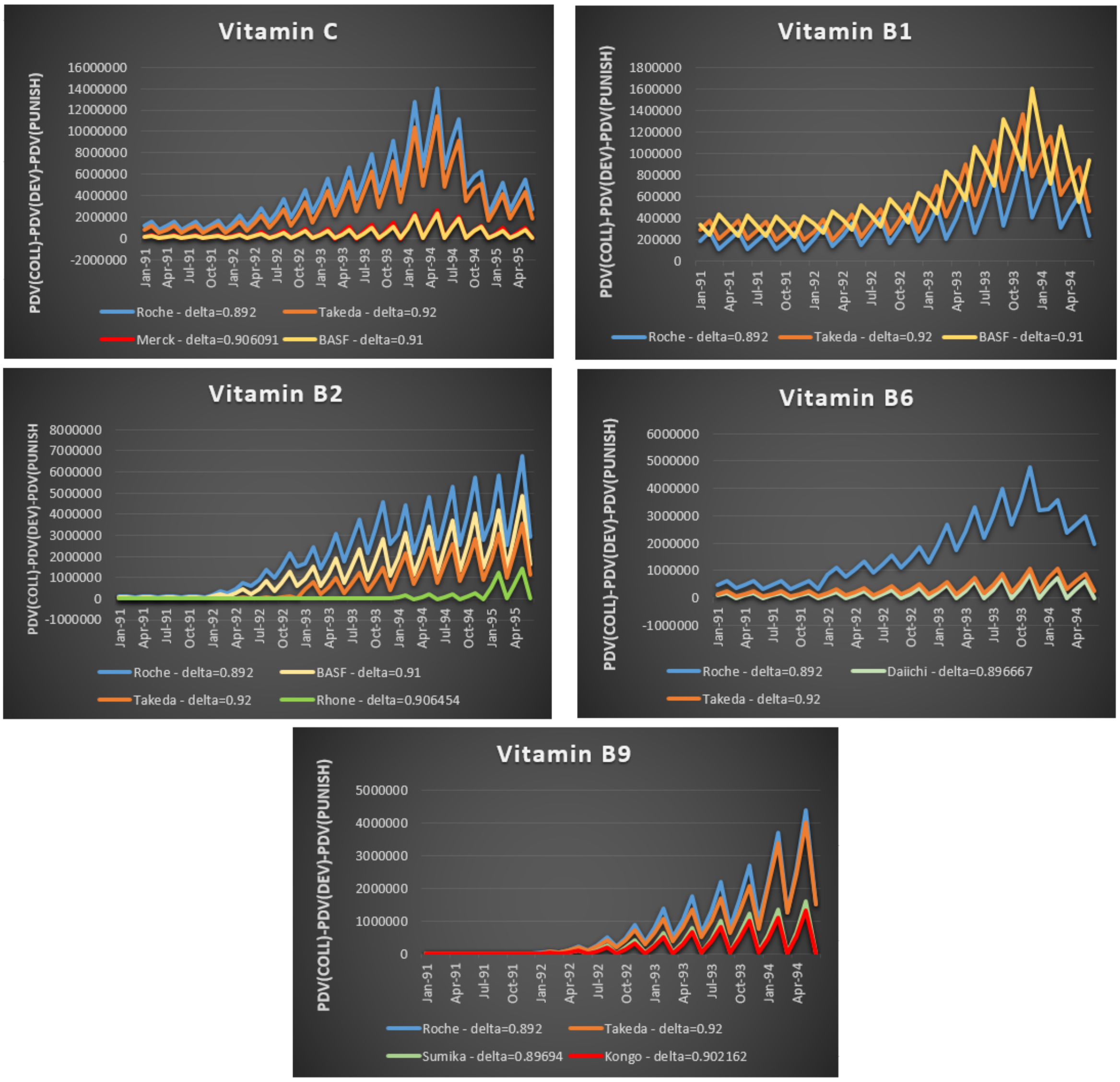
5.4.3 Scenario 1 - cartels' breakdown when they work in isolation

In this section we discuss the case when all cartels operate in isolation, however, Roche,Takeda and BASF discount their future profits in all cartels by the same δ.
The analysis of firms' collusive behaviour suggests only one possible scenario, explaining the breakdown of the cartels under the assumptions in this case:

1. Roche, Takeda and BASF did not cause the breakdown of any of the agreements, i.e. $\delta^{Roche} \geq 0.892$, $\delta^{Takeda} \geq 0.92$ and $\delta^{BASF} \geq 0.91$;
2. Merck breaks vitamin C cartel, so $\delta^{Merck} = 0.906091$;
3. Rhone breaks vitamin B2 cartel, so $\delta^{Rhone} = 0.906454$;
4. Daiichi breaks vitamin B6 cartel, so $\delta^{Daiichi} = 0.896667$;
5. Sumika and/or Kongo break vitamin B9 cartel, so $\delta^{Sumika} \geq 0.89694$ and $\delta^{Kongo} \geq 0.902162$, one of which holds with equality;
6. Vitamin B1 cartel breaks down due to internal disagreements;

Figure 5.1 illustrates all firms' incentive to collude in each cartel for the above-mentioned discount factors for 1991-1994/95:

Figure 5.1: Scenario 1 - Cartels' Breakdown When They Operate in Isolation



However, this scenario does not prove to be plausible due to the following inconsistencies:

- The assumption that Roche, Takeda and BASF use the same discount factor in all cartels they participate in, in combination with the analysis of their behaviour for each δ we controlled for, implies that all cartel breakdowns have been caused by firms, participating in only 1 cartel;
- However, Merck, Rhone and Daiichi exhibit problematic behaviour before 03/1994 for the discount factors which make their IC=0 in 03/1994. I.e. for these deltas they would have defected earlier. The existence of vitamin C,B2 and B6 cartels

until mid 1994/95 therefore suggests that each cartel first tried to deal with their problematic behaviour before breaking down.

- The breakdown of vitamin B1 cartel remains unexplained under this scenario;

5.4.4 Scenario 2 - cartels' breakdown in case of multi-market contact

The simultaneous breakdown of all five cartels can, however, be explained in the context of multi-market contact. **What if the major participants did not treat every industry in isolation, but instead determined whether to cooperate by combining their profits under collusion from all cartels they worked in?** Put differently, in the case of multi-market contact the major participants do not break individual cartels whenever their IC gets negative, as long as their combined IC is positive in the same time period. This strategy is much more flexible, for it allows companies to maximise their total profits by using collusive agreements as a form of compensation (Appendix, Section 8.5).

Under the assumption of existing multi-market contact, the analysis of firms' collusive behaviour yields the following scenario, explaining the simultaneous breakdown of all cartels:

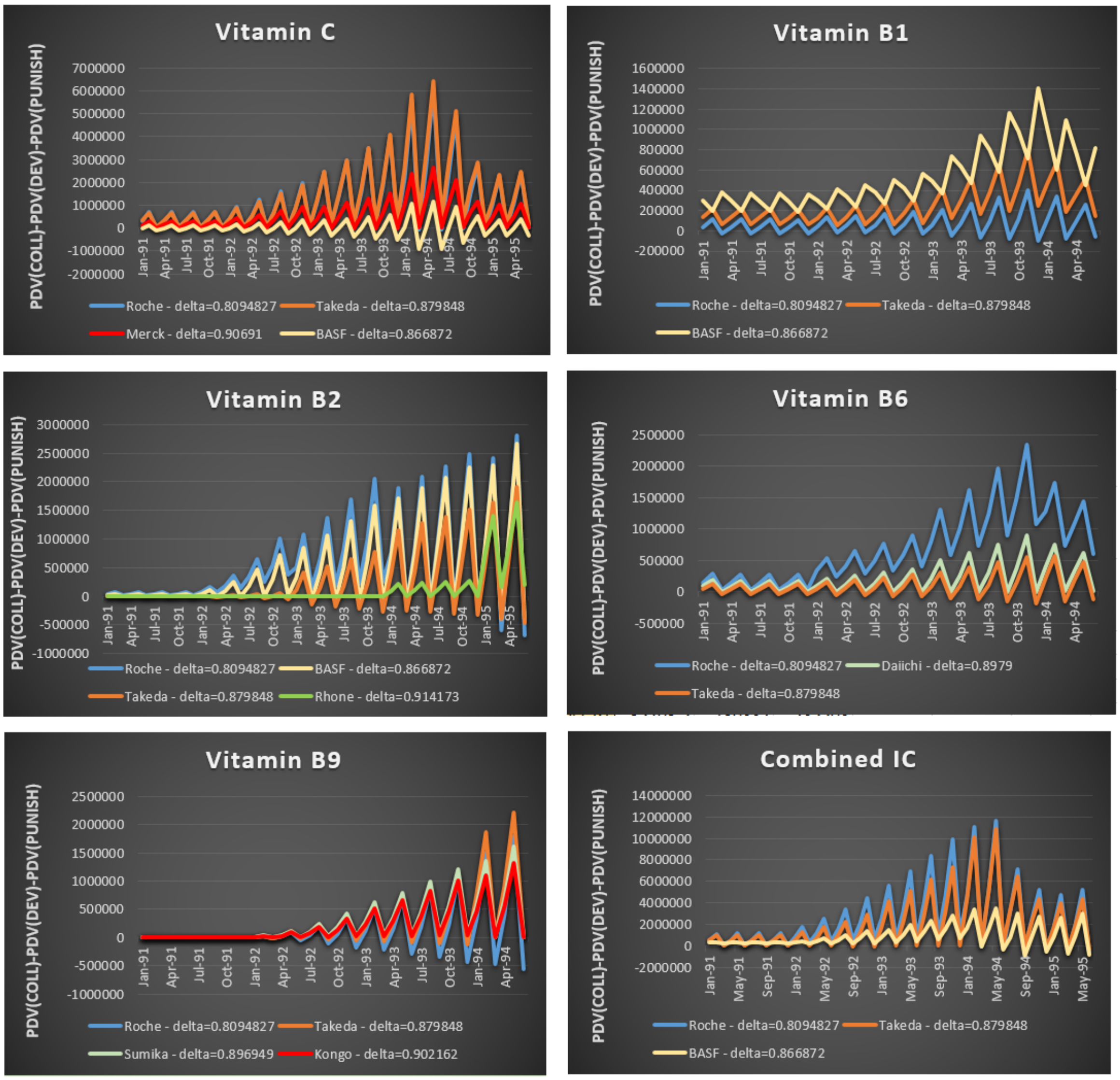
1. Roche is the reason for the simultaneous breakdown of all cartels. This happens when its combined IC becomes zero in 03/1994 - $\delta^{Roche} = 0.8094827$;

2. Takeda and BASF have positive combined IC throughout the whole period 1991-1994, so $\delta^{Takeda} \geq 0.879848$ and $\delta^{BASF} \geq 0.866872$;

3. Merck, Rhone, Daiichi, Sumika and Kongo have positive IC throughout the whole period 1991-1994, so $\delta^{Merck} \geq 0.90691$, $\delta^{Rhone} \geq 0.914173$, $\delta^{Daiichi} \geq 0.8979$, $\delta^{Sumika} \geq 0.896949$ and $\delta^{Kongo} \geq 0.902162$;

Figure 5.2 illustrates all firms' incentive to collude in each cartel for these discount factors. The last graph shows the combined ICs for the major players Roche, Takeda and BASF, which determine their incentive to collude in all industries they operate in.

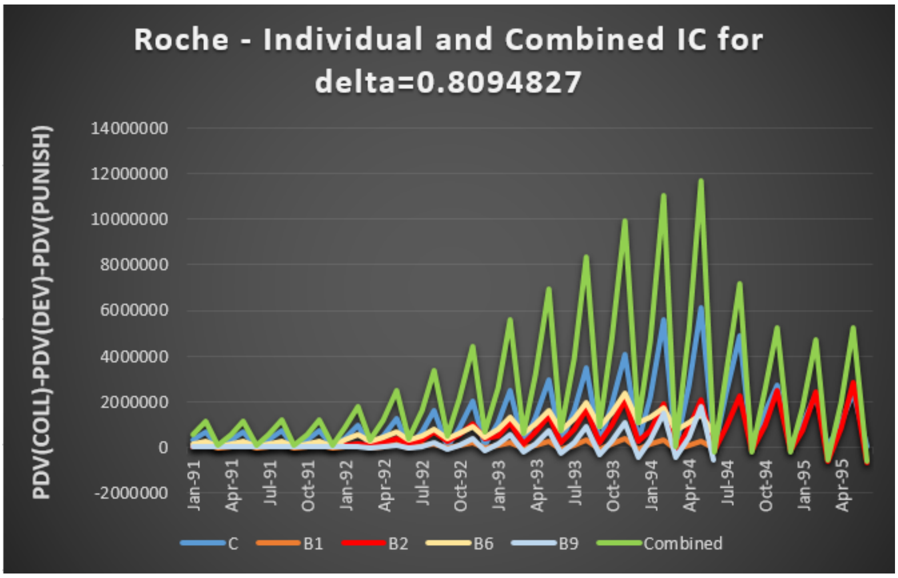
Figure 5.2: Sceanrio 2 - Cartels' Breakdown In Case Of Multi-Market Contact



5.5 The effect of Multi-Market Contact

The previous discussion indicates the effect of multi-market contact on the outcome of the simulations. According to the analysis, there exists a threshold for Roche's, Takeda's and BASF's discount factors, after which the sustainability and simultaneous breakdown of all cartels are entirely attributed to the existence of multi-market contact.
To better illustrate this observation, consider the following Figure:

Figure 5.3: Roche - Individual And Combined IC Analysis For $\delta = 0.8094827$



The graph shows Roche's individual and combined IC for $\delta = 0.8094827$, which was used in Scenario 2. If Roche was to treat each cartel in isolation, it would have deviated from the vitamin B1 and B9 cartels much earlier, for its IC in these cartels becomes negative in every 3 months. However, when Roche treats the agreements altogether, all 5 cartels break down in mid 1994. Similarly, for the discount factors in Scenario 2 Takeda and BASF would have deviated from vitamin B2, B6, B9 and vitamin C and B2 cartels, respectively, if they treated them in isolation. However, when they consider their total profits, no one wants to deviate from the agreements. (Further discussion - Appendix, Section 8.5)

6 Limitations and Further Discussion

The major limitation of this project is the insufficient available data, used for the empirical analysis of firms' collusive behaviour. Although the theoretical framework and the recreation of missing data are built on assumptions, closely replicating the concrete historical characteristics of each vitamin industry (documented by John Connor [3]), the use of estimated monthly values for the main variables in the model instead of their real values could have led to errors in the calculations. Therefore, this project aims at providing an intuitive explanation for the reasons behind the enforcement and breakdown of collusive agreements, rather than delivering an accurate empirical evaluation.
The results from the simulations might be different from the historical events, their sole purpose is to underpin numerically the theoretical analysis of collusive behaviour!

7 Concluding Remarks

The theoretical and empirical analysis in this project confirms the complex nature of collusive agreements and the correlation between their sustainability and numerous factors such as cartel members' size, capacity constraints, discount factors and ability to detect and punish deviations, just to name a few.

However, the highlight of this project is that multi-market contact has a positive effect on cartels' sustainability. The different outcomes from the simulations in the presence and absence of such contact verify my initial hypothesis that multi-market contact between all five cartels could explain their simultaneous breakdown.

The stability of collusive agreements can be influenced and even entirely attributed to the existence of multi-market contact!

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8 Appendix

8.1 Data Recreation and Calibration of the Theoretical Model

For the purpose of conducting an empirical analysis, I had to run numerous simulations in order to evaluate each firm's collusive behaviour and the factors, which affected it. However, as already mentioned in Section 4, the available data only comprised of each firm's global market share for 1990-1995, the market price and the global share of fringe supply for the same time period, and the amount of global production at the end of 1990. Based on this data and the information about the number of cartel firms for each year in the period 1990-1995, I have estimated the annual values of the four main variables - the slope of the inverse demand curve α, the demand shifter X_t, the marginal cost c_t and the amount of real fringe supply $Q^{real}_{fri,t}$.
We do this by using the theoretical model and the equations, describing each market regime, and by using backwards induction.
Once we have derived these values for December each year, we proceed to determining the dynamics of the market. In order to do this, we make the following assumptions, which are justified by the historical evidence for stable demand and fringe supply growth in the period (1990-1995)[3]:

- The slope of the inverse demand curve α stays constant (only exception is vitamin C cartel, where we allow for adjustments of α for 1994 and 1995);
- The marginal cost stays constant;
- We allow for monthly adjustments of the demand shifter X_t, which captures the increase of the market demand in each industry;
- We allow for monthly adjustments of the fringe supply $Q^{real}_{fri,t}$, which captures its steady increase/fall;

The adjustments of the demand shifter and the fringe supply, introduced in the model, are mathematically given by the following simple recurrence relation:

$$X_{t+1} = X_t + y \tag{8.1}$$
$$X_{t+2} = X_{t+1} + y = X_t + 2y \tag{8.2}$$
$$... \tag{8.3}$$
$$X_{t+12} = X_t + 12y \tag{8.4}$$

Similarly for the fringe supply.
Once we know the values of these variables for December each year, we are able to calculate their monthly values for the period 1991-1994/1995.
Here are the tables, containing information about P_t, $Q_{cartel,t}$, $Q^{real}_{fri,t}$, α, X_t and c_t for December, 1990-1994/95 for each of the cartels. The initial available data is in red, whereas the data in white represents my estimations of the missing variables:

Table 8.1: Initial Data for Vitamin C cartel

Vitamin C - values for December						
	1990	1991	1992	1993	1994	1995
Price	11.50	12.00	13.00	14.00	14.40	15.20
Q cartel	4350000.00	3414021.16	5742063.49	8070105.82	9001322.75	3426315.79
Q fringe	650000.00	421957.67	1250000.00	1500000.00	4235916.59	2100000.00
alpha	-0.0000004	-0.0000004	-0.0000004	-0.0000004	-0.0000004	-0.0000014
Demand sh.	31772486.77	31772486.77	37256613.76	42162698.41	46761048.86	16686768.73
MC	10.53	10.53	10.53	10.53	10.53	10.53
Global Production Shares						
	1990	1991	1992	1993	1994	1995
Roche	0.45000	0.46000	0.43210	0.42711	0.35000	0.32000
Takeda	0.26000	0.26000	0.25942	0.26115	0.21000	0.19000
Merck	0.09000	0.10000	0.07539	0.08340	0.07000	0.06000
BASF	0.07000	0.07000	0.05432	0.07161	0.05000	0.05000
Fringe:	0.13000	0.11000	0.17877	0.15674	0.32000	0.38000
Intra-Cartel Market Shares						
	1990	1991	1992	1993	1994	1995
s -R	0.51724	0.51685	0.52616	0.50649	0.51471	0.51613
s -T	0.29885	0.29213	0.31589	0.30969	0.30882	0.30645
s -M	0.10345	0.11236	0.09181	0.09890	0.10294	0.09677
s -B	0.08046	0.07865	0.06614	0.08492	0.07353	0.08065

Table 8.2: Initial Data for Vitamin B2 Cartel

Vitamin B2 - Values for December						
	1990	1991	1992	1993	1994	1995
Price	42.5	43	50	55	57.8	60.6
Q cartel	178000	145155.08	609326.2032	940877.0053	1126545.45	1312213.904
Q fringe	22000	21689.8396	91048.74301	140590.8169	125171.717	83758.33428
alpha	-0.0000151	-0.0000151	-0.0000151	-0.0000151	-0.0000151	-0.0000151
demand sh.	3018181.818	3018181.82	4015882.968	4728526.646	5084444.44	5414367.96
MC	40.81	40.81	40.81	40.81	40.81	40.81
Global Production Shares						
	1990	1991	1992	1993	1994	1995
Roche	0.56000	0.54000	0.47502	0.45588	0.44000	0.42000
BASF	0.30000	0.30000	0.26709	0.26970	0.27000	0.26000
Takeda	0.03000	0.03000	0.12789	0.14442	0.17000	0.17000
Rhone	0.00000	0.00000	0.00000	0.00000	0.02000	0.09000
Fringe:	0.11000	0.13000	0.13000	0.13000	0.10000	0.06000
Intra-Cartel Market Shares						
	1990	1991	1992	1993	1994	1995
s -R	0.62921	0.62069	0.54600	0.52400	0.48889	0.44681
s -B	0.33708	0.34483	0.30700	0.31000	0.30000	0.27660
s -T	0.03371	0.03448	0.14700	0.16600	0.18889	0.18085
s -Rh	0.00000	0.00000	0.00000	0.00000	0.02222	0.09574

Table 8.3: Initial Data for Vitamin B1 Cartel

Vitamin B1 - Values for December						
	1990	1991	1992	1993	1994	1995
Price	27	28	29	32	27.2	
Q cartel	297500	226867.232	282234.4633	448336.1582	288273.863	
Q fringe	52500	67765.5367	165756.7483	263308.5374	192182.575	
alpha	-0.0000181	-0.0000181	-0.0000181	-0.0000181	-0.0000181	
Demand sh.	1844915.254	1844915.25	2053640.929	2483396.108	1986445.14	
MC	23.90	23.90	23.90	23.90	23.90	
Global Production Shares						
	1990	1991	1992	1993	1994	1995
Roche	0.38206	0.36222	0.28000	0.28000	0.30000	
Takeda	0.36000	0.31000	0.27000	0.27000	0.22000	
BASF	0.10794	0.09778	0.08000	0.08000	0.08000	
Fringe	0.15000	0.23000	0.37000	0.37000	0.40000	
Intra-Cartel Production Shares						
	1990	1991	1992	1993	1994	1995
s -R	0.44949	0.47042	0.44444	0.44444	0.50000	
s -T	0.42353	0.40260	0.42857	0.42857	0.36667	
s -B	0.12698	0.12698	0.12698	0.12698	0.13333	

Table 8.4: Initial Data for Vitamin B6 Cartel

Vitamin B6 - Values for December						
	1990	1991	1992	1993	1994	1995
Price	25	30	36	46.5	32.9	
Q cartel	191250	137823.087	197160.7923	301001.776	236609.495	
Qfringe	21255	28228.8251	76673.64147	277847.7932	201556.237	
alpha	-0.0001011	-0.0001011	-0.0001011	-0.0001011	-0.0001011	
demand sh.	462740.4372	462740.437	629860.6633	1038716.782	763534.147	
MC	16.06	16.06	16.06	16.06	16.06	
Global Production Shares						
	1990	1991	1992	1993	1994	1995
Roche	0.43000	0.49000	0.50000	0.34000	0.38000	
Daiichi	0.15000	0.12000	0.12000	0.09000	0.08000	
Takeda	0.14000	0.12000	0.10000	0.09000	0.08000	
Fringe	0.10000	0.17000	0.28000	0.48000	0.46000	
Merck	0.10000	0.00000	0.00000	0.00000	0.00000	
BASF	0.08000	0.00000	0.00000	0.00000	0.00000	
Intra-Cartel Market Shares						
	1990	1991	1992	1993	1994	1995
s -R	0.47778	0.67123	0.69444	0.65385	0.70370	
s -D	0.16667	0.16438	0.16667	0.17308	0.14815	
s -T	0.15556	0.16438	0.13889	0.17308	0.14815	
s -M	0.11111	0.00000	0.00000	0.00000	0.00000	
s -B	0.08889	0.00000	0.00000	0.00000	0.00000	

Table 8.5: Initial Data for Vitamin B9 Cartel

Vitamin B6 - Values for December						
	1990	1991	1992	1993	1994	1995
Price	25	30	36	46.5	32.9	
Q cartel	191250	137823.087	197160.7923	301001.776	236609.495	
Qfringe	21255	28228.8251	76673.64147	277847.7932	201556.237	
alpha	-0.0001011	-0.0001011	-0.0001011	-0.0001011	-0.0001011	
demand sh.	462740.4372	462740.437	629860.6633	1038716.782	763534.147	
MC	16.06	16.06	16.06	16.06	16.06	
Global Production Shares						
	1990	1991	1992	1993	1994	1995
Roche	0.43000	0.49000	0.50000	0.34000	0.38000	
Daiichi	0.15000	0.12000	0.12000	0.09000	0.08000	
Takeda	0.14000	0.12000	0.10000	0.09000	0.08000	
Fringe	0.10000	0.17000	0.28000	0.48000	0.46000	
Merck	0.10000	0.00000	0.00000	0.00000	0.00000	
BASF	0.08000	0.00000	0.00000	0.00000	0.00000	
Intra-Cartel Market Shares						
	1990	1991	1992	1993	1994	1995
s -R	0.47778	0.67123	0.69444	0.65385	0.70370	
s -D	0.16667	0.16438	0.16667	0.17308	0.14815	
s -T	0.15556	0.16438	0.13889	0.17308	0.14815	
s -M	0.11111	0.00000	0.00000	0.00000	0.00000	
s -B	0.08889	0.00000	0.00000	0.00000	0.00000	

Once we have managed to recreate the data set needed in order to calibrate the theoretical model, we proceed to calculating each firm's optimal production level in each of the three regimes, the market price (or in the Deviation Regime - the secret price supposed to induce the targeted level of sales), as well as the expected and real profits made by each cartel member.
The calculations for each cartel are made individually and correspond to the specifications of the collusion, accounting for cartel members, exiting the market, or new entrants, as well as internal agreements between firms which we are informed about(such agreement exists between Roche and BASF in the vitamin B1 cartel - BASF does not produce, however it buys a specified amount of production from Roche at a favourable price, which we assume to be equal to the marginal cost, and then re-sales it at the market price - see Appendix, Section 8.5.1).

8.2 No Capacity Constraints in Deviation Regime - Implications

The role of Capacity Constraints proved to be of utmost importance for the sustainability of any of the cartels. As already discussed, the implementation of production restriction is compulsory in regime Punishment, when the market reverses to Cornout competition. The absence of capacity constraints in the case of firms with identical marginal costs of production leads to a static Cournot-Nash equilibrium in which all companies produce the same quantity. However, according to the documented information, different firms had different global production shares, which can only be explained by the existence of

capacity constraints.
However, the need of capacity constraints in regime Deviation does not become obvious solely from the theoretical model. In addition, the short maximal duration of defecting - 3 months, suggests that every company can meet their targeted sales levels by using inventories, in case it decides to deviate.
Sections 5.1 and 5.2 discuss the observations, made after running simulations, based on this assumption. The most obvious one is that in the absence of capacity constraints in Deviation regime, the smaller the company, the greater the profit from defecting and the greater the "secret" price reduction.
To illustrate this, consider a simple comparison between the profits of Roche (intra-cartel market share of appr.50%) and Merck (appr. 10%) under collusion and after deviation in the vitamin C cartel:

Table 8.6: Roche - change in profits and reduction of price - Deviation - vit C

	Roche - Collusion Regime			Roche - Deviation Regime			Comparison	
date	Cartel Price	Quota	Exp. Profit	Dev output	secret P	Dev. Exp.profit	Price reduction	Profit increase
Jan-91	11.95	1706896.55	2419525.86	2503448.28	11.61	2692070.15	-2.86%	11.26%
Feb-91	11.95	1706896.55	2419525.86	2503448.28	11.61	2692070.15	-2.86%	11.26%
Mar-91	11.96	1717619.55	2450021.04	2519175.33	11.62	2726000.42	-2.88%	11.26%
Apr-91	11.96	1717619.55	2450021.04	2519175.33	11.62	2726000.42	-2.88%	11.26%
May-91	11.96	1717619.55	2450021.04	2519175.33	11.62	2726000.42	-2.88%	11.26%

Table 8.7: Merck - change in profits and reduction of price - Deviation - vit C

	MERCK - Collusion Regime			MERCK - Deviation Regime			Comparison	
date	Cartel Price	Quota	Exp. Profit	Dev output	secret P	Dev. Exp.profit	Price reduction	Profit increase
Jan-91	11.95	341379.31	483905.17	1820689.66	11.32	1423904.88	-5.32%	194.25%
Feb-91	11.95	341379.31	483905.17	1820689.66	11.32	1423904.88	-5.32%	194.25%
Mar-91	11.96	343523.91	490004.21	1832127.51	11.32	1441851.46	-5.35%	194.25%
Apr-91	11.96	343523.91	490004.21	1832127.51	11.32	1441851.46	-5.35%	194.25%
May-91	11.96	343523.91	490004.21	1832127.51	11.32	1441851.46	-5.35%	194.25%

This observation implies that smaller companies have greater incentive to deviate.The way to prevent them from defecting is therefore to:

1. Either restrict their production in regime Deviation by introducing capacity constraints, or

2. Provide enough punishment power to their rivals, which reduces the profits of the defecting firm enough so as to compensate the gains from deviation;

This conclusion leads to the implementation of new, more realistic assumptions in the model, which were discussed in Section 5.3.

The introduction of Capacity Constraints in regime Deviation can also be seen as a tool for controlling another aspect beyond the scope of the theoretical model - namely the

magnitude of the "secret" price reduction. Detection of deviation is possible not only on the quarterly meetings of the chiefs of global vitamins marketing, held for monitoring purposes, but also on the basis of detected price reductions above the accepted norms by the cartel. [9].
We do not have any specific information about the price deviations, considered as acceptable by the cartels, which to incorporate in the theoretical model. Therefore, the implementation of capacity constraints in Deviation regime partially solves this problem, for it restricts the production of the defecting firm and so lowers the magnitude of the "secret" price cut.

8.3 Roche, Takeda and BASF - individual discount factor analysis

In this section you can find the tables for the individual discount factors of Roche, Takeda and BASF. They indicate each firm's:

- discount factor for which its IC=0 in March 1994/1995;
- behaviour for this δ before 03/1994 and thus shows whether this company could have been the reason for the breakdown of the cartel;
- threshold for δ after which its IC is positive (i.e. the firm has no incentive to defect)

Table 8.8: Roche - individual discount factor analysis

Capacity Constraint = 1.3* Intra-Cartel Production Quota							
Roche							
Cartel:	Discount factor for which IC=0 in 03/1994	Company's behaviour before 03/1994	Could this company have been the reason for the cartel's breakdown in 06/1994?	Discount factor for which IC=0 in 03/1995	Company's behaviour before 03/1995	Could this company have been the reason for the cartel's breakdown in 06/1995?	Discount factor threshold, after which IC is +ve
vitamin C	0.810481	Positive IC up to 03/1994	YES	0.806445597	Negative IC in 3 months after 03/1994	NO	0.810481
vitamin B1	0.83616	Positive IC up to 03/1993, after which IC=0 in 3 months	NO	-	-	-	0.83616
vitamin B2	0.818573	Positive IC up to 03/1994	YES	0.835314	Positive IC up to 03/1995	YES	0.835314
vitamin B6	0.686616	Negative IC in every 3 months	NO	-	-	-	0.786595409
vitamin B9	0.844088	Negative IC in every 3 months after 03/1992	NO	-	-	-	0.85

Table 8.9: Takeda - individual discount factor analysis

Capacity Constraint = 1.3* Intra-Cartel Production Quota							
Takeda							
Cartel:	Discount factor for which IC=0 in 03/1994	Company's behaviour before 03/1994	Could this company have been the reason for the cartel's breakdown in 06/1994?	Discount factor for which IC=0 in 03/1995	Company's behaviour before 03/1995	Could this company have been the reason for the cartel's breakdown in 06/1995?	Discount factor threshold, after which IC is +ve
vitamin C	0.873159	Negative IC in every 3 months	NO	0.873342107	Negative IC in every 3 months	NO	0.877
vitamin B1	0.841627	Negative IC in every 3 months	NO	-	-	-	0.85
vitamin B2	0.926193	Negative IC in every 3 months	NO	0.926976	Negative IC in every 3 months	NO	0.92
vitamin B6	0.896667	Negative IC in every 3 months	NO	-	-	-	0.901236952
vitamin B9	0.879848	Negative IC in every 3 months	NO	-	-	-	0.892

Table 8.10: BASF - individual discount factor analysis

Capacity Constraint = 1.3* Intra-Cartel Production Quota							
BASF							
Cartel:	Discount factor for which IC=0 in 03/1994	Company's behaviour before 03/1994	Could this company have been the reason for the cartel's breakdown in 06/1994?	Discount factor for which IC=0 in 03/1995	Company's behaviour before 03/1995	Could this company have been the reason for the cartel's breakdown in 06/1995?	Discount factor threshold, after which IC is +ve
vitamin C	0.907678	Negative IC in every 3 months	NO	0.90892993	Negative IC in every 3 months after 03/1993	NO	0.91
vitamin B1	-	Positive IC	NO	-	-	-	all discount f-r
vitamin B2	0.875178	Positive IC up to 03/1994	YES	0.879795	Positive IC up to 03/1995	YES	0.879795

The observations of this discount factor analysis, indicated by the tables above, serve as a basis for table 5.4: Major Players - sign of IC before 03/1994 in Section 5.5.2.
Table 5.4 shows the collusive behaviour of Roche, Takeda and BASF in all five cartels under the assumption that they use the same discount factor in all industries they operate in. The tables in this section of the Appendix provide information about these companies' collusive behaviour when we control their individual IC to be zero 3 months before the breakdown of each cartel. The results from these tables, therefore, allow for

finding scenarios, explaining the breakdown of the cartels, when:

- All cartels work in isolation;
- Roche, Takeda and BASF discount their future profits in each cartel by different discount factors (i.e. unlike in section 5.5.2, here the discount factor is completely determined by the industry and not the firm's characteristics and structural organisation)

8.3.1 One Possible Explanation for the Breakdown of the Cartels

The most plausible scenario, explaining the breakdown of the cartels under the assumptions, mentioned in the previous section, is the following:

1. Roche breaks vitamin C cartel. The rest of the cartel members have positive IC throughout the whole period 1991-1994: $\delta^{Roche} = 0.810481$,$\delta^{Takeda} \geq 0.877$, $\delta^{BASF} \geq 0.91$, $\delta^{Merck} \geq 0.906091$;
2. Roche breaks vitamin B2 cartel. The rest of the firms have positive IC throughout the whole period 1991-1995: $\delta^{Roche} = 0.835314$, $\delta^{Takeda} \geq 0.92$, $\delta^{BASF} \geq 0.879795$, $\delta^{Rhone} \geq 0.939608$;
3. Daiichi breaks vitamin B6 cartel. The rest of the firms have positive IC throughout the whole period 1991-1994: $\delta^{Roche} \geq 0.786594$, $\delta^{Takeda} \geq 0.9012369$, $\delta^{Daiichi} = 0.896667$;
4. Sumika or Kongo break vitamin B9 cartel. The rest of the firms have positive IC throughout the whole period 1991-1994: $\delta^{Roche} \geq 0.85$, $\delta^{Takeda} \geq 0.892$, $\delta^{Sumika} \geq 0.896949$, $\delta^{Kongo} \geq 0.902162$ with one strict equality for Kongo or Sumika;
5. The breakdown of vitamin B1 cartel remains unexplained by the discount factor analysis.

Although this is the most plausible explanation for the breakdown of the cartels under the assumptions, mentioned above, it involves some inconsistencies. First, it does not explain the breakdown of vitamin B1 cartel. However, as we shall see, there is an agreement between Roche and BASF within this cartel, so its breakdown may be attributed to some internal disagreements. Second, according to this scenario, Daiichi must have been the reason for the breakdown of vitamin B6 cartel. However, the analysis shows that for this discount factor, its IC becomes negative before mid 1994, i.e. Daiichi exhibits problematic behaviour.

These inconsistencies serve as an evidence in favour of the existence of multi-market contact, which was used to explain the cartels' breakdown in section 5.5.3.

8.4 **Discount Factor - the Intuition Behind It**

The analysis of firms' collusive behaviour after we've implemented adjusted capacity constraints in both Deviation and Punishment regimes indicated the impact of the discount factor on the enforcement and sustainability of the cartels. In the previous sections we've discussed different possible scenarios, explaining the breakdown of these agreements, in which scenarios we've assigned different δ-s to each company so as to guarantee the cartels' breakdown in mid 1994/95 and firms' unproblematic behaviour up to that moment. But what stands behind the values of these discount factors? The following observations might help us answer this question:

- Smaller firms in terms of global market shares tend to exhibit unproblematic collusive behaviour for higher discount factors than larger firms do; I.e. the threshold for δ after which firms'IC is positive, is higher for smaller firms.
- Roche, Takeda and BASF exhibit unproblematic collusive behaviour for higher discount factors, when they treat each cartel in isolation, compared to the discount factors, guaranteeing their unproblematic behaviour in the case of multi-market contact.

How can we interpret these results? Intuitively, the first observation states that if all firms discount their future identically, smaller ones are less prone to obey the collusive agreements. This means that the profits from Deviation and in Punishment regime are relatively higher for smaller firms. This result confirms one of the earlier observations, which states that smaller firms make relatively higher profits when defecting than larger firms do. At the same time, companies with higher intra-cartel market share are assigned a higher production quota, and so benefit more from the higher price-setting under collusion. Therefore, their behaviour is more in favour of the cartel's sustainability.

The intuition behind the second observation is a natural extension of the previous one. If the threshold for δ after which the major participants exhibit unproblematic behaviour, is higher, when cartels operate in isolation, then the multi-market contact facilitates the sustainability of collusive agreements. In other words, cartels with the same participants are more stable, when these firms treat them altogether, i.e. care about the combined profits from all cartels.

8.5 **What Makes the Multi-Market Contact attractive?**

When firms meet the same rivals in multiple markets, their competitive behaviour might be different from that of the single-market companies. Multi-market contact has the same effect on collusive behaviour as well. We already discussed how it can be used for explaining the simultaneous breakdown of the cartels, examined in the paper (section 5.4.4). After analysing the correlation discount factor - collusive behaviour, we also discovered that the multi-market contact facilitates the sustainability of cartels. What is the intuition behind these results?

Multi-market contact gives a firm the opportunity to respond to its rivals' actions not only in one particular market, but in all markets they both operate in. In the context of the Vitamin Conspiracy, this means that the major participants - Roche,Takeda and BASF, can impose the credible threat of punishing any deviation from a collusive agreement by breaking all cartels they participate in. This is consistent with the literature, confirming the importance of the punishment credibility[2], and is backed by the empirical analysis in the project.
Another reason for the positive effect of multi-market contact on the cartels' sustainability, is the fact that it gives firms the option to maximise their profits by using cartels as a form of compensation. This might have been the case of the vitamin B1 cartel.

8.5.1 The Case with the Vitamin B1 Cartel

The collusive agreement between Roche, Takeda and BASF in the vitamin B1 market is somewhat peculiar. Although only Roche and Takeda produce, BASF is an equal participant in the cartel, it buys production from Roche (at price, assumed to be equal to the MC in the simulations), then re-sells it at the collusive price level. Clearly BASF cannot deviate from this cartel, and clearly, it has no incentive to do so, because it only benefits from it. However, Roche clearly loses from this agreement, for it could enjoy the profits from selling the production, promised to BASF, at the market price. What might be then the reason for this agreement? One possible explanation is that the vitamin B1 cartel serves as a compensation for BASF for cooperating in the markets for vitamin C and B2.

To better illustrate the idea, consider the following situation: After analysing the markets for vitamin C and B1, Roche concludes that it would make considerable profits if it organises a vitamin C cartel with the participation of BASF. However, BASF does not benefit from colluding in this market - it exhibits problematic collusive behaviour. In this situation, Roche can provide BASF with an incentive to cooperate by offering it to cooperate in the market for vitamin B2. If BASF benefits enough from the second cartel, it will accept the offer to participate in both cartels. As long as the Roche's profits from the vitamin C cartel minus the losses from the vitamin B1 cartel exceed the profits under competition in both markets, Roche will organise the two cartels. In this case the vitamin B1 cartel serves as a compensation tool for BASF.

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