

PRICE DEVELOPMENTS
IN POST-CARTEL PERIODS

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People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices.

— Adam Smith in *The Wealth of Nations* (1776)

ABSTRACT

This paper examines price developments in post-cartel period, a topic that hitherto has not been subject to much academic research. For that purpose, the research question is approached from both a theoretical and an empirical angle, in an attempt to uncover the dynamics of post-collusive pricing behavior. Following the introduction, the second chapter is dedicated to a theoretical analysis that combines classic and behavioral economics, industrial organization, and sociology and extends existing models in order to establish five hypotheses on post-cartel pricing. All hypotheses point towards the fact that post-cartel prices in general are above the competitive level, that could otherwise have been expected but for the existence of the cartel. The five hypotheses are as follows:

1. Given non-efficient markets, the immediate post-cartel prices are expected to be above the competitive level
2. Post-cartel prices are expected to be higher in markets where the post-cartel period is characterized by a litigation phase
3. Residual collusion can lead to abnormally high post-cartel prices
4. As price variance is generally larger during competitive periods than under collusive ones, a non-competitive post-cartel period is expected to exhibit below-average price variation
5. Due to reciprocity, post-cartel periods triggered by whistle blowing or deviation from an agreement, are expected to be characterized by above-average competition

In chapter three, part of the theoretical findings are tested empirically using publicly available data on the case of the German cement cartel from 1991 to 2002. Pricing behavior is analyzed using conduct parameters - an estimate of market power - following the method laid out by Bresnahan (1982) and Lau (1982). Alas, the empirical analysis does not support nor reject the theoretical predictions. Finally, recommendations are given as to how the remaining hypotheses can be tested empirically.

Keywords: Post-cartel pricing, cartels, collusive pricing, German cement cartel, residual collusion, reciprocity, conduct parameter method

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INTRODUCTION

What happens within an industry after a cartel has been fined and dissolved? Is it likely that the cartel members continue to operate and to compete with one another? Some of the largest fines imposed by the European Commission have been levied on large transnational companies which are still active and supposedly competing with their previous fellow conspirators, such as Phillips, Deutsche Bank and Roche. While it is commonly believed that such prosecutions have borne fruit with regards to re-establishing a competitive climate, this paper investigates whether previous cartel members did change to a competitive behavior, following their conviction by anti-trust authorities.

The aim is thus to examine whether the post-collusive period is truly characterized by fully competitive behavior - or instead whether firms continue to collude to some extent. As Adam Smith puts it in his notorious *Wealth of Nations* from 1776: "*People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices*" (Book II, Chapter X, Part II, p. 152).

With the above-mentioned questions in mind, the aim of this master's thesis is to investigate how prices develop in the post-cartel period, and to identify the drivers of these price developments. One intuition is that prices return to their non-collusive equilibrium immediately following a cartel's termination; another that this transition happens gradually. Or on the contrary, one could argue that prices might never return to the competitive level, and that cartels continue to affect prices even after being officially dissolved. The discussion of the potential price developments in the post-cartel period is at the core of this master's thesis.

1.1 PROBLEM STATEMENT

This thesis will analyze the price developments in post-cartel periods, i.e. the period of time following a cartel breakdowns. It is based on a research proposal originally outlined by Prof. M. Asplund, Ph.D., of Copenhagen Business School.

Based on the initial questions formulated in the introduction, the research question that will be answered is the following:

RESEARCH QUESTION How do prices develop in the post-cartel period in comparison to what could have been expected, but for the existence of the cartel?

The overall research question will be answered using more specific sub-questions, as follow:

1. From a theoretical point of view, how are prices expected to develop in the post-cartel period compared to both the pre-cartel and collusive period?
2. How do the theoretically derived hypotheses regarding the post-collusive price relate to the price developments empirically observable?

1.2 PURPOSE, MOTIVATION AND LEGITIMATION

Most contemporary research on collusion, antitrust, and cartels, within the field of industrial organization, focuses on either overcharge estimation or leniency programs, and on how new legislation affects collusive behavior. Research investigating how collusion and cartels affect prices does rarely investigate what happens after a cartel is dissolved. As Bolotova et al. (2008) puts it: "*[a]n important issue, that has found a very limited attention in both theoretical and empirical literature, is cartel pricing during the post-cartel period. It has crucial implication for calculation of damages during antitrust litigations*", (p. 1292). Hitherto, no comprehensive theory on post-collusive pricing exists. This master's thesis therefore aims at contributing to filling this gap.

A significant amount of theoretical and empirical research on cartel cooperation is available. Much of the existing theoretical research has addressed cartel sustainability and those aspects supporting it. Some of the most cited are Abreu et al. (1986), Bagwell and Staiger (1997), Green and Porter (1984), Porter (1983b), and Rotemberg and Saloner (1986).¹ One conclusion from this literature is that the success of a cartel - in maintaining high prices - depends on market-specific characteristics such as the presence of demand shocks and asymmetries in both costs and demand (Levenstein & Suslow, 2006).

Based on these theoretical models a substantial empirical literature has formed, using structural econometric models for the study of cartels. Examples include Ellison (1994), Porter (1983a) and Röller and Steen (2003). In the more descriptive literature are numerous studies of individual cartels in which the authors study the duration of the cartel, how prices were raised, and the mechanisms used to prevent companies from "cheating" or "defecting". A small selection of these studies are Bolotova et al (2008), Connor (1997), Hausman (1984), Marshall et al (2008), and Symeonidis (2003) and White (1999).

¹ See Levenstein and Suslow (2006) for further references.

However, as valuable as these studies are, they are not able to answer the question regarding the effect of the cartel itself on prices in the post-collusive period.

1.3 LIMITATIONS AND DELIMITATIONS

Carrying out empirical analyses on cartels and collusion is often a troublesome exercise, due to the illegal and therefore hidden nature of cartels. This leads to two limitations: first, data gathering is very difficult; and second, it is difficult to assert with an acceptable degree of certitude that the selected sample (consisting exclusively of discovered cartels) is representative of the general "population" of cartels. This creates a potential selection bias in the data (Gujarati, 2009). It is therefore important to keep this risk of a selection bias in mind moving forward, especially when interpreting the findings and results of the empirical analysis.

A further limitation, but deliberate, is no exclusive investigate price developments in the markets under scrutiny, as opposed to non-price variables. Indeed, economic theory states that increased prices is only one - amongst many - manifestation of collusion. Colluding firms can also benefit through coordination of advertising and/or innovation, lower competition through higher barriers to entry, etc. Such non-price variables will not be included in the present analysis.

1.4 METHOD

To answer our research question and establish some general statements about post-cartel pricing, it is deemed an appropriate method to approach the problem from two angles: a theoretical and an empirical angle. The first part of the analysis will deal with post-cartel pricing from a theoretical point of view, and establish five hypotheses regarding post-collusive pricing. As no existing models deal explicitly with post-cartel pricing, our analysis will build on existing general research within the field of industrial organization, economics and finance, as well as original research. The theoretical analysis will be inductive of nature.

The second part of the analysis will deal with the research question from an empirical point of view. As it proved to be extremely difficult, if not impossible, to obtain the relevant and necessary data (during the data gathering process), the empirical analysis will focus on testing one out of the five hypotheses on a case and give recommendations as to how the remaining four can be tested, in a situation where data would be available. Consequently, the empirical analysis chapter also aims at giving sound recommendations to further research within the area of post-cartel pricing and competition.

As touched upon in the limitations section above, data on cartels is notoriously difficult to obtain. My attempts to obtain price and quantity data on the organic peroxide cartel from the European Commission through an official request was aborted, as I was denied access to such. The rejection was motivated by the sensitivity of the information, as it was deemed that a public disclosure of this information would undermine the protection of the companies' commercial interest. The official letter of rejection from the European Commission, dated October 16th 2013, can be found as appendix [A.1](#). An attempt to obtain price and quantity information from trade journals and similar third party observers was likewise unsuccessful, as such information was not stored by the publishers.

Turning to the validity of the findings, it is acknowledged that the external validity of the empirical analysis is relatively low, as it is conducted on a single case, making generalization difficult (Saunders et al., 2009). This is due to the fact that systematic theoretical hypothesis testing requires a large sample of case studies for the conclusions reached to be externally valid (Moses and Knutsen, 2007).

1.5 STRUCTURE

This thesis is structured as follows: in section 2 a number of theoretically deduced hypotheses will be constructed from a theoretical point of view, using both existing literature and original research. These hypotheses will be tested and discussed empirically, and the results presented and evaluated in section 3. Finally, chapter 4 will conclude by synthesizing the key findings, and will as well outline suggested directions for future research within the field of post-collusive pricing.

THEORETICAL ANALYSIS

This section will take a theoretical point of view, on how prices can be expected to develop in the post-cartel phase. Throughout the analysis, a number of hypotheses on post-cartel pricing will be developed, using existing research and original findings. The development of these hypotheses will be the main contribution of this chapter, and will be used as a point of departure for the empirical analysis in chapter 3.

In the present analysis the *post-cartel phase* is defined as *the period of time immediately following a cartel breakdown, discontinuance or termination*. The period differs from case to case, and is thus to be determined qualitatively in each situation. Further, the "triggers" of the post-cartel periods differ; some cartels come to an end as the result of an anti-trust authority raid or investigation, while other cartels naturally dissolve and are not uncovered until years later - if ever. This also means that some post-cartel periods are characterized by public and/or private litigation, while in other cases the previously colluding firms continue to operate as if nothing happened. A third example could be a post-cartel period characterized by an intense price war, potentially an attempt by previous conspirators to punish one or several members that deviated from the collusive agreement. As this brief discussion has uncovered, post-cartel periods are not a homogeneous mass. The definition therefore has to be broad and qualitative of nature in order to grasp the vast differences in post-cartel periods.

This theoretical analysis of pricing in the post-cartel period is structured as follows: first, general theories on collusion and cartels are reviewed, with specific focus on collusive pricing. Second, post-collusive pricing is discussed and analyzed, leading to the development of the five hypotheses. Finally the findings are synthesized.

2.1 THEORY OF COLLUSION

In order to understand how collusive pricing differs from a competitive equilibrium, it is important to understand the fundamentals of collusive behavior and cartels. Thus, this section is devoted to give the reader a brief introduction to the theoretical basics of cartels and collusion.

As the focal point of this thesis is cartels, it is necessary to have a clear definition of the term. Pepall et al. (2008) define a cartel as "a group of firms who have agreed explicitly among themselves to coordinate their activities in order to raise market price - that is, they have entered into some form of price-fixing agreement", (Pepall et al.,

2008). It is worth noting that this definition emphasizes that the observed behavior should be *explicit*. In practice, collusion can be either explicit or *tacit*, a necessary distinction to examine.

EXPLICIT VERSUS TACIT COLLUSION The main difference between these two types of collusion hinges on how agreements are reached within the cartel. Harrington (2005) defines tacit collusion as "*when firms engage in a pricing arrangement that serves to raise price and [this] is achieved without explicit communication*" (p. 160). In other words, under tacit collusion firms coordinate their activities simply by observing and anticipating other firms' behavior. On the contrary, "*explicit collusion is when firms engage in direct communication regarding the setting of prices*" (p. 160). Often the firms involved agree on a common plan of action, as well as exchange mutual assurances to follow the agreed-upon plan. The distinction between explicit and tacit collusion is essential, as the two types are treated differently in most legal contexts (Connor, 2000). Interestingly, such distinction is not very well-aligned with economic theory. As pointed out by Harrington (2005), "*there is a gap between antitrust practice which distinguishes [between] explicit and tacit collusion and economic theory which (generally) does not*".

The definition of a cartel by Pepall et al. refers exclusively to explicit cartels. However, as we are not interested in excluding tacit collusion, a more comprehensive definition is needed. The definition set forth by Levenstein & Suslow (2008) is broader, and will be used throughout this thesis:

DEFINITION A cartel is an association "*of independent firms that restrict output or set prices*" (Levenstein & Suslow, 2008).

Cartels are formed with the purpose of limiting competition in order to increase profits, and are generally illegal in most jurisdictions today. By entering into a collusive agreement, the cartel members can optimize the joint profit and thus replicate the monopoly outcome. Following the formation of a cartel, its members are said to face three key problems: cheating, coordination and new entries. Stigler (1964) states - in his seminal work on collusive oligopolies over the time - that cheating is the main threat to cartel sustainability. The temptation to break the collusive agreement comes from the fact that the cooperative monopoly outcome is normally never a Nash equilibrium. In other words, breaking the agreement is generally the best response irrespective of the action of the counter-part(s). At the monopoly price, each firm's mark-up is quite large, giving each and every cartel participant an incentive to cut prices or increase output marginally. If all firms follow this incentive, the collusive equilibrium will not be sustainable and the cartel will collapse. Not only is the cartel agreement

undermined by the self-interest of its members, it is further weakened by the fact that cartels are illegal *per se*. The agreements are therefore rarely formalized and often covert, thus difficult to uphold in practice. (Pepall et al., 2008)

Because it is expected that the reader is familiar with basic industrial organization theory on collusion,¹ and due to space restrictions, this will not be presented here. Basic theory on how the collusive equilibrium differs from the competitive one can be found in Pepall et al. (2008).

As mentioned above, in the traditional oligopoly approach, the collusive equilibrium is not stable, as each firm has an incentive to deviate by increasing output or lowering price. However, by introducing the notion of *repeated interaction* from game theory, collusive behavior can be sustained in the long run (Feuerstein, 2005). Consider an infinitely repeated oligopoly game - also known as a *super game* - consisting of an infinite repetition of the stage game. Further, assume that each firm follows a *grim trigger strategy*, i.e. if a firm defects by producing a higher output than agreed upon, all other firms play their non-cooperative strategy of the stage-game in all following stages (the punishment is triggered), (Friedman, 1971).

Let $0 < \delta < 1$ denote the discount factor, t the period, π^{i*} firm i 's cooperative per period profit, π^{iD} the one-period profit from deviating, and π^{iP} the per period profit following deviation. In this setting, for firms to refrain from cheating, cartel members must choose continued cooperation and shared profit over the one-period full monopoly profit. That is:

$$\pi_{\text{coll}}^i = \sum_{t=0}^{\infty} \delta^t \pi^{i*} = \frac{1}{1-\delta} \pi^{i*} \quad (1)$$

must be larger than or equal to

$$\pi_{\text{coll}}^i = \pi^{iD} + \sum_{t=1}^{\infty} \delta^t \pi^{iP} = \pi^{iD} + \frac{\delta}{1-\delta} \pi^{iP} \quad (2)$$

This can also be written as:

$$\delta \geq \delta^{i*} = \frac{\pi^{iD} - \pi^{i*}}{\pi^{iD} - \pi^{iP}} \quad (3)$$

For collusion to be sustainable, this inequality must hold. As $\delta^{i*} < 1$, this is true if δ is close enough to unity, i.e. firms are *sufficiently patient*. More formally, collusion is sustainable if there is a sub-game perfect equilibrium resulting in the designated collusive outcome. (Feuerstein, 2005)

¹ With basic theory within the field of collusive behavior, I am referring to profit optimization as a cartel, and how the collusive equilibrium differs from the competitive with regards to price, quantity and social welfare.

Equation (3) shows that the no-deviation constraint is more likely to hold if the punishment is more severe, i.e. if π^{iP} is low. In other words, the threat of fierce competition helps to stabilize collusion.

As proven in the above, the patience of firms is an important factor in cartel sustainability. There is an extensive and comprehensive academic literature studying which *other* factors - besides the patience of firms - facilitate or hinder collusion. In their 1974 paper *An Empirical Survey of Price Fixing Conspiracies*, Hay & Kelley identify a number of factors for potential collusive success, whereas the most important are: small number of firms, high market concentration and product homogeneity. Other factors that can be said to facilitate collusion include significant entry barriers, frequent and regular orders, rapid market growth, technological or cost symmetry, and multi-market contact, (Pepall et al., 2008).

ARE PRICES ALWAYS HIGHER DURING CARTELS? Classic industrial organization theory prescribes that collusive behavior generally leads to elevated prices, resulting in a loss of social welfare. As such, it is common belief that anti-trust prosecution results in lower prices (Sproul, 1993). However, not all economists agree on this, as some argue that in certain situations, cartels can be cost-reducing. By cooperating on areas such as research or advertising, colluding firms can obtain cost advantages that ultimately can result in lower prices (Bork, 1978). Sproul (1993) investigates whether antitrust prosecution raises or reduces prices. Using data from before and after a new anti-trust statute was introduced in the U.S. in the year 1974, Sproul finds that prices rose by 7% over the four years following an indictment. In other words, anti-trust activity seemed to do more harm than good. The finding supports the hypothesis by Bork (1978), and suggests that some of the penalized cartels are indeed economically efficient. In relation to post-cartel pricing, this indicates that we can expect to observe prices above the collusive price level.

During the court hearings following the notorious citric acid cartel in the 1990s, it was even suggested that the cartel simply alleviated an abnormal level of competition (Connor, 2000). It should nevertheless be noted that supporters of this argument are a minority, and that most economists agree that collusive agreements and price fixing constitute a threat to social welfare. This majority stand is further supported by legislations in place around the world, including the United States and the European Union, criminalizing collusive behavior.

2.1.1 *Cartel Pricing in the Presence of Anti-trust*

As an extension to the classic economic theories on cartel pricing outlined above, Harrington (2005) formulated a dynamic model to ex-

plore cartel pricing in the presence of anti-trust authorities. In the models presented here so far, no such thing is taken into consideration. The objective of Harrington's model is to evaluate and understand the impact of various anti-trust policies on cartel pricing and behavior. He finds that the steady-state collusive price is decreasing in the damage multiple and in the probability of detection, but is neutral to the fixed fines (as opposed to findings in previous studies). Due to space limitations, and because it is mainly of conceptual importance to our research question, the model itself will not be replicated here.

Harrington further finds that the steady-state cartel price is below the theoretically implied monopoly price when the firm takes damage payments into consideration - but equals the monopoly price when the only penalty is fixed fines. The important distinction is that damages are a function of observed collusive prices, while fixed fines are obviously fixed at a certain level depending on the felony committed. The optimal² steady-state cartel price P^* , assuming the presence of an anti-trust authority, is given as the solution to (following the notation of Harrington (2005)):

$$\pi'(P^*) = \left[\frac{\delta \hat{\phi}(0)}{1 - \delta\beta(1 - \hat{\phi}(0))} \right] \times \gamma x'(P^*) \quad (4)$$

$x(P^*)$ is the level of damages in the current period, γ is the multiple³ of damages, $\hat{\phi}(\cdot)$ is the probability-of-detection function, δ the discount factor, and $1 - \beta$ a measurement of the rate of deterioration of evidence on collusive conduct. The intuition is that the optimal price is obtained when the marginal profit of a price change (left-hand side) equals the expected present value of the marginal change in damages (right-hand side). Further, using comparative statics, Harrington finds that "*the steady-state cartel price is reduced when (i) the damage multiple, γ , is increased; (ii) the probability of detection, $\hat{\phi}(\cdot)$, is increased; (iii) the rate at which damages persist over time, β , is increased; and (iv) the discount factor, δ , is increased*", (Harrington, 2005, p. 156). Finally, Harrington's results give an insight into the transitional dynamics of prices, when moving from a competitive to a collusive equilibrium. Prices are expected to gradually increase until they reach the collusive steady-state level, as it is assumed that period-to-period price changes are what drives the probability of detection. This is a quite remarkable result, which is very well aligned with what can be observed in reality.

While all of the above results are relevant, the first finding on the optimal cartel price level has particular implications for our analysis. It indicates that the theoretically implied optimal collusive price overestimates the level that can be observed in reality. This is an important consideration when assessing whether prices in different periods are

² The optimal steady-state cartel price is derived under numerous assumptions, which can be found in Harrington's paper.

³ As an example, U.S. anti-trust law prescribes treble damages, i.e. $\gamma = 3$

the outcome of a competitive or a collusive equilibrium - and the finding will be applied later, in section 3.3.4.

Now that the theoretical foundation of collusive pricing in general has been laid out, let us turn to the nexus of this thesis: post-cartel pricing. Harrington (2004)'s reflection is quite telling: "*post-cartel off-equilibrium prices are troublesome*" (p. 530). As mentioned in the introduction, hitherto no comprehensive industrial organization model predicting post-cartel price movements has been established. The following section will take its starting point in existing research, which offers good indications as to how prices might develop in the post-collusive market. These models will be extended or modified, in order to establish five hypotheses aiming at predicting price developments in the post-cartel market.

2.2 POST-COLLUSIVE PRICING

Taking a holistic approach, spend a moment considering what possible outcomes one could expect in the post-cartel phase. In short, prices can either increase, remain constant or decrease. Further, such a change in price level can happen either relatively instantaneously or gradually. Ignore for a second the absolute level of the post-cartel prices and simply assume that the post-collusive price is determined by a unique competitive Nash equilibrium, \hat{P} , given n firms in the market where P is the average price, $P = \frac{\sum_{i=1}^n P_i}{n}$. Thus, two possibilities exist: an immediate return to the competitive equilibrium price or a fade-out transitional path. These two possibilities are treated in turn here, and both rely on the assumption that prices will return to a competitive equilibrium level, \hat{P} .

2.2.1 Immediate Return to Competitive Level

Without further proof, we assume that, given a certain market structure, a unique competitive equilibrium exists. Under Bertrand oligopoly, as well as perfect competition, this implies $\hat{P} = MC$, while a Cournot oligopoly is characterized by $\hat{P} = \frac{a}{n+1} + \frac{n \times MC}{n+1}$, (Pepall et al., 2008). The steady-state price in the competitive equilibrium, regardless of the type of competition, is denoted \hat{P} . In our model, consumers only know their own demand but not the aggregate one, and are generally not able to tell if price changes are a result of cost changes, demand shifts or collusive behavior.

Now assume that at time t_0 a cartel agreement is established, where prices are agreed fixed at a future time t_1 at the optimal collusive level P_c . Further assume that anti-trust authorities are present, and that the probability of detection is a function $\phi(P_{t-1}, P)$, increasing in the changes in prices from period to period. Following the findings

of Harrington (2005), the optimal behavior of the cartel members, is to gradually increase prices to the new collusive level. Say that the colluding firms are able to convince the customers in the market, that the price changes are not a result of non-competitive behavior, i.e. they are successful in implementing and sustaining P_c . In period t_2 the anti-trust authorities uncover the cartel and begin the indictment, which ends in t_3 where the anti-trust case is concluded and a fine levied. Given a constant number of firms as well as constant costs and aggregate demand $\forall t$, price is expected to return to the competitive equilibrium \hat{P} following the indictment.

The question is now how the transition to the competitive equilibrium takes place. In order to understand this transition, we can introduce a relevant theory from outside the field of industrial organization; *the efficient market hypothesis*. This theory states that, given strong market efficiency, prices are to reflect all information on a particular market, (Bodie et al., 2009). This theory has been developed to - and is normally applied in - evaluating changes in stock prices. However, using this theory, and assuming strong efficiency and complete information implies that, at the moment of anti-trust authorities uncovering the cartel, prices should immediately revert to the competitive level. In an environment with no external shocks and constant demand and costs, this leads to a graphical representation of the price development as can be seen in figure 1.

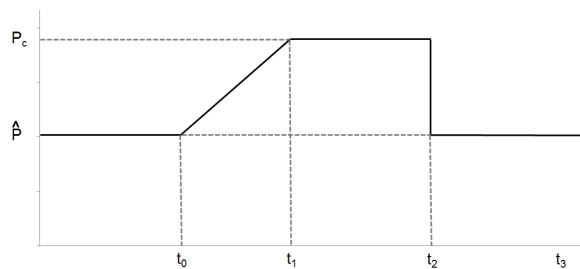


Figure 1: Immediate return of prices to competitive level

There is no doubt that such an increase in prices between t_0 and t_1 is easier to conceal with external shocks and varying costs and demand - two parameters present in reality. However, the assumption of strongly efficient markets is very strict, and rarely - if ever - observed in reality. In order to illustrate what pattern is instead often observed in reality, the case of the graphite electrodes cartel is introduced. The cartel that took place between 1992 and 1997 makes a good case, as post-cartel prices arguably exceeded the competitive price level several years after the indictment (Harrington, 2004). Below, the reader can find a graph showing nominal prices of graphite electrodes from 1992 to 2000.

As can be seen from figure 2, prices increased steadily until June 1997 where the cartel came to an end. This way of gradually increasing prices correspond well to the findings of Harrington (2005) discussed

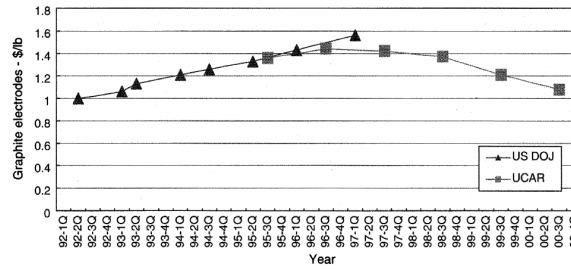


Figure 2: Graphite electrode prices 1992-2000. Source: Harrington (2004)

in section 2.1.1. What is interesting is to observe how prices gradually declined in the quarters following the cartel breakdown in the end of the second quarter of 1997. We do not observe a pattern similar to that predicted in figure 1. As a matter of fact, Harrington (2005) finds that even two years after the graphite electrode cartel breakdown, prices were still more than 20% above pre-cartel level.

As illustrated by this example, and supported by many others not presented here, the theory of an immediate return of prices to the competitive level seems inadequate in explaining post-cartel pricing behavior. This leads to the next step of this analysis, where prices are allowed to gradually converge to the new competitive equilibrium.

2.2.2 Price Changes with Transitional Dynamics

In order to allow for gradual convergence, proceed by relaxing the assumption of efficiency, and introduce another theory, from outside the world of classic industrial organization; the theory of *price rigidities*. Continue to assume that the firm has a sincere incentive to adjust prices back to the competitive level \hat{P} as quick as possible. However, assume that not all companies are able to adjust the price exactly at time t_2 . This can be modelled using so-called *Calvo pricing*, which states that only a fraction of all companies are able to adjust prices in response to a shock (change in competitive environment) in period t_2^4 , (Calvo, 1983). Recall that \hat{P} is an expression for the average price in the market over n firms. Normally this theory is used to evaluate responses to monetary shocks, e.g. in New Keynesian macroeconomic models. Introducing Calvo pricing enables us to establish a model closer to what is observable in reality. A natural follow-up question is to ask why it should simply be assumed that all firms cannot adjust prices immediately following the shock of a change of competitive structure. As an answer to this, some qualitative arguments can be made. One suggestion is that in reality firms are heterogeneous, and thus implement price changes at different pace - thus the assumption

4 More specifically, it states that all firms have a probability θ of adjusting their price in period t . However, on an aggregate level, using the law of large numbers, this is the same as stating that only a fraction θ of all firms n can adjust prices.

of homogeneous firms must be relaxed. Second, one can argue that if a higher price during the collusive period has increased margins, this in turn can have inflated costs. It seems plausible that higher margins can lead to less prudence in spendings.⁵ Given that costs might be larger during the collusive period, firms might wish to reduce these costs before lowering prices, in order to remain profitable.

The result in this model - which is only shown conceptually, not yet proved mathematically - is that the average price does not immediately converge to the new competitive level. With such transitional dynamics, the price reaches \hat{P} at time t^* which is necessarily bound by $t_2 \leq t^*$, depending on the rate of convergence. Note that the graph below is a highly stylized representation of how prices might converge in reality.

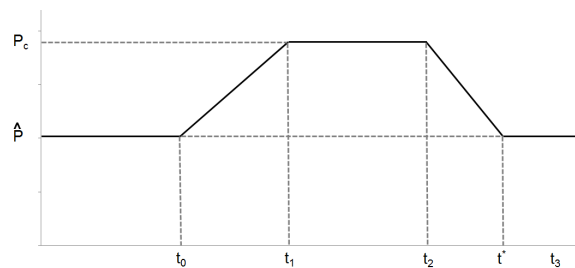


Figure 3: Price changes with transitional dynamics

As such, the price behavior as seen in figure 3 can be explained by price rigidities and non-efficient price dynamics. One criticism could be that anti-trust authorities can easily observe that prices are not adjusted to the new competitive equilibrium. However, this relies on the assumption that the new equilibrium is public knowledge and there is full consensus about the price level - which is not found plausible in reality. It is more likely that anti-trust authorities simply expect a price range and not a specific price level. Further, it is not expected to see such stylized price developments as presented above in reality, where price changes as a result of regime variations will be entangled with price changes due to demand and cost shocks. This discussion leads us to the first hypothesis:

Hypothesis 1 *Given non-efficient markets, the immediate post-cartel prices are expected to be above the competitive level.*

It is worth emphasizing that so far prices have only been expected to remain above the competitive equilibrium level in the short term. In the long run however, the assumption remains that prices converge to the new level. As such, both of the above two possible post-cartel price development scenarios rely on the assumption that prices would

⁵ One can imagine how high profits can lead to relocations to new headquarters, purchases of new private jets for management, etc.

ultimately revert back to the competitive level after the cartel breakdown. Further, it has been assumed that firms have a genuine intention to revert prices to the competitive level as quickly as possible. However, a question arise here: is it a plausible belief that prices will adjust back to the non-collusive equilibrium instantly or relatively quickly following an indictment? Further, one can wonder if firms have an actual interest in this, or might have incentives to artificially maintain inflated prices. The latter possibility will be treated in the following.

2.2.3 *Strategic Pricing During Litigation*

A third possible reasoning behind post-cartel prices is that the previously colluding firms have an incentive to maintain abnormally inflated price levels in the post-cartel period, contrary to our assumption in the preceding. One possible explanation to such behavior can be found in Harrington (2004), where firms internalize damage payments from litigations in their post-cartel pricing. This is implemented in theory by accounting for the endogeneity of anti-trust penalties. In his 2004 paper, Harrington carries out an economic analysis of post-cartel pricing during litigation, and shows that companies - after having been convicted of participating in a cartel - have an incentive to set prices above the competitive equilibrium, in order to minimize damages payable.⁶ Using the post-cartel prices as an expression for the competitive equilibrium leads to an overestimation of the but-for price⁷ and in turn an underestimation of the anti-trust damages and overcharges. Harrington further finds that the upward bias in the but-for price is greater the longer the cartel duration and the higher a concentration in the industry.

While Harrington's model deals with prices during litigation phases, it is the belief of this author, that the model can be expanded to explain how prices might develop in the general post-cartel period, which might or might not be characterized by litigation. In the following, Harrington's original model will be derived. Thereafter a discussion of what changes are to be implemented, for the model to work in a general post-cartel development.

The below derivation of the theoretical model of pricing during litigation is based on Harrington (2004). It is assumed that damages are calculated using the *before-and-after*⁸ approach for estimating cartel overcharges.

⁶ Here Harrington makes the assumption that the but-for price, and thus the damages, are estimated using a before-and-after method. Such a method is only one of many available when assessing overcharges during cartels, however it is the most widely used in damage assessment.

⁷ The but-for price is the price that would have prevailed during the collusive period, but for the existence of the cartel.

⁸ For a review of the before-and-after approach please refer to section 3.3.1

THE MODEL Firms are assumed to interact as in a standard oligopoly model with n firms offering differentiated products. Let $\pi(P_i, P_{-i})$ denote the profit of firm i , when it charges a price of P_i while the remaining competitors prices at P_{-i} . π is assumed to be twice continuously differentiable and strictly concave in P_i , such that a best response function ψ exists and is unique. Finally, assume that the own price effect dominates. Then a unique symmetric Nash equilibrium, denoted \hat{P} , exists. $D(P)$ is the demand given a price of P , and it is assumed that the equilibrium price results in a positive demand, such that firms are active.

In this model we distinguish between three regimes, that is the pre-cartel, cartel and post-cartel. The post-cartel is here defined as the period between the dissolution of the cartel and the conclusion of litigation. By further assuming stationary cost and demand characteristics, the but-for price can be determined as a weighted average of the price prevailing during the pre- and post-cartel periods:

$$p^{bf} = \alpha p^{pre} + (1 - \alpha) p^{post} \quad (5)$$

p^{bf} is the but-for price, p^{pre} the pre-cartel competitive price, and p^{post} the post-cartel price. α is the weight given to the post-cartel data, and is a decreasing function of p^{post} that takes a value in the range $[0;1]$. α is set to take a value of zero if the post-cartel price is above the cartel price, as price data is not deemed likely to be included in a damage estimation in practice. Given the above expression for the but-for price, the overcharge can be estimated by:

$$\theta D(P^c) [P^c - (\alpha p^{post} + (1 - \alpha) p^{pre})] \quad (6)$$

where P^c is the price during the cartel and θ is a multiplier applied to damages.⁹

In the post-cartel period, the active firms set their price in a simultaneous game with the pay-off function:

$$V(P_i, P_{-i}) \equiv \pi(P_i, P_{-i}) - \theta D(P^c) [P^c - (\alpha p^{post} + (1 - \alpha) p^{pre})] \quad (7)$$

where $p^{post} = \frac{1}{n} [P_i + (n - 1) P_{-i}]$. The pay-off function V is assumed to be strictly concave, that is the second derivative must be less than zero:

$$\begin{aligned} \frac{\delta^2 V^2(P_i, P_{-i})}{\delta P_i^2} < 0 \Leftrightarrow \frac{\delta^2 \pi(P_i, P_{-i})}{\delta P_i^2} \\ + \theta D(P^c) \frac{1}{n^2} [\alpha''(p^{post})(p^{post} - p^{pre}) + 2\alpha'(p^{post})] < 0 \quad (8) \end{aligned}$$

As $\frac{\delta^2 \pi(P_i, P_{-i})}{\delta P_i^2} < 0$ and $\alpha'(p^{post}) \leq 0$, the above expression holds if $\alpha''(p^{post})$ is not large, which is thus a sufficient condition we impose

⁹ As an example, treble damages, i.e. a multiplier of three, are to be paid by convicted companies in the US

for V to be strictly concave. The optimality condition for firm i is determined by the first order condition with respect to P_i , which we define as ϕ :

$$\begin{aligned} \phi(P^*) \equiv \frac{\delta V(P^*, P^*)}{\delta P_i} &= \frac{\delta \pi(P^*, P^*)}{\delta P_i} \\ &+ \theta D(P^c) \left(\frac{1}{n} \right) [\alpha'(P^*) (P^* - P^{pre}) + \alpha(P^*)] = 0 \quad (9) \end{aligned}$$

It can then be shown that the equilibrium is unique given our previous assumptions. We now turn to the task of uncovering the relationship between P^c and P^* . This is done by working out from the assumption that $P^c > P^*$, and proving this mathematically. The following derivation is a direct replication of the proof given in Harrington (2004) p. 524:

To establish that $P^c > P^*$, first note that $\theta(P^c) < 0$ since $\delta \pi(P^c, P^c)/\delta P_i < 0$, $\alpha(P^c) = 0$, and $\alpha'(P^c) \leq 0$. Given $\theta'(P) < 0$ then $P^c > P^*$. As $P^*(0) = \hat{P}$, if $P^*(\theta)$ is shown to be strictly increasing in θ then it immediately follows that $P^*(\theta) \geq \hat{P} \forall \theta$. Since $\delta^2 V(P^*, P^*)/\delta P_i^2 < 0$ then, by the usual arguments, if $\delta^2 V(P^*, P^*)/\delta P_i \delta \theta > 0$ then $\delta P^*/\delta \theta > 0$.

$$\frac{\delta^2 V(P^*, P^*)}{\delta P_i \delta \theta} = D(P^c)(1/n)[\alpha'(P^*)(P^* - \underline{\mu}) + \alpha(P^*)] \quad (10)$$

and, from the first-order condition,

$$\theta D(P^c)(1/n)[\alpha'(P^*)(P^* - \underline{\mu}) + \alpha(P^*)] = -\frac{\delta \pi(P^*, P^*)}{\delta P_i} > 0 \quad (11)$$

Hence, $\delta^2 V(P^*, P^*)/\delta P_i \delta \theta > 0$.

This leads to:

THEOREM 1 If $\theta' > \theta'' > 0$ then $P^c > P^*(\theta') > P^*(\theta'') > \hat{P}$.

This is the main result of Harrington (2004). The above expression states that the post-cartel price level is below that of cartel pricing but above that of a competitive equilibrium. The intuition behind this result stands as follows: by internalizing the damage payments in its pricing decision, the firm prices above the level that maximizes profits - *ceteris paribus* - and thus it lowers the amount of expected damages payable, as the firm's post-cartel price in turn is used in the assessment of overcharges.

The result can also be derived more intuitively, by assuming that all firms in the post-cartel period price at P_c . Firm i can benefit by lowering its price marginally, thus increasing its current profits *and*

lowering the damages payable by raising the but-for price, as α is a function of P^{post} and becomes marginally larger than zero (recall that α is assumed to be zero when the average post-collusive price is equal to or greater than the collusive price). On the other hand, by lowering the price, P_i , holding α constant, firm i reduces the but-for price thus increasing the damages payable. However, as $\alpha = 0$ for $P^{\text{post}} = P^c$, this effect is not present when lowering the post-collusive price marginally from P^c , but manifests when price is further decreased. Continuing with this logic results in a post-cartel price between the collusive and the non-collusive equilibrium price.

Harrington further derives a measure for the strategic pricing bias, i.e. the difference between the strategic price p^* and the non-strategic price \hat{p} :

$$\frac{p_t^* - \hat{p}_t}{\hat{p}_t} = \frac{f(X)g(Z)}{h(n, Z)} \quad (12)$$

X is a set of variables that captures the weight that firms put on damages, n the number of cartel members, and Z a vector of demand and cost shifters.

The hypothesis is thus as follows: cartels that are dismantled and followed by an anti-trust investigation, will, *ceteris paribus*, maintain post-cartel prices above the non-collusive equilibrium in the short term. It is important to note that Harrington's theory does not predict that prices will remain at this abnormal level for a longer period of time, but only during the litigation phase. If there is a sequence of court cases, the firm will place less and less weight on damages as these get settled. This is manifested by a decrease in θ over time, which results in a gradual increase in the post-cartel price, in accordance with the pattern that can be observed in the case of graphite electrodes (see figure 2).

The hypothesis would be testable given a larger data sample of cartels. If a cartel ceases to exist before an investigation is initiated, the post-cartel price pattern should deviate from that of pricing in a market where an investigation triggered the cartel to come to an end. More specifically, such a difference should be captured in the model by a lower value of θ . We would thus expect to see a longer transition period to the competitive equilibrium in the latter case, assuming that the cartel period is not followed by another non-competitive equilibrium such as tacit collusion.

The pattern that can be observed in a post-collusive period where strategic pricing is present will thus be very similar to that shown in figure 3 (transitional dynamics), even though the explanation differ with regard to the intention of the firms. However, given Harrington's findings, we can expect the fade-out to last until the end of the litigation process, as this is the optimal behavior for the previously colluding firm.

EXTENDING HARRINGTON'S THEORY TO GENERAL POST-CARTEL PERIODS To sum up, Harrington's theory predicts that the post-cartel price will be above the competitive level during the litigation phase. However, I argue that this finding does not *only* apply in post-cartel markets *already characterized by a litigation phase*. Assume that any colluding firm will assign a probability γ to the possibility that their illegal activities will be uncovered, and they will face a litigation phase. Further assume that $0 < \gamma \leq 1$, i.e. the firm will never know with certainty, that it will not face litigation. Implementing this in firm i 's pay-off function (7), and naming it W , yields:

$$W(P_i, P_{-i}) \equiv \pi(P_i, P_{-i}) - \gamma\theta D(P^c)[P^c - (\alpha P^{\text{post}} + (1 - \alpha)P^{\text{pre}})] \quad (13)$$

Further define Z , as the "standard" profit optimization faced by a firm i , i.e. disregard strategic pricing:

$$Z(P_i, P_{-i}) \equiv \pi(P_i, P_{-i}) \quad (14)$$

As is evident $\lim_{\gamma \rightarrow 0} W = Z$, while $\lim_{\gamma \rightarrow 1} W = V$. Further, in order to simplify the following steps, and because γ is simply a constant expressing firm i 's expectations, define:

$$\hat{\theta} = \gamma \times \theta \quad (15)$$

As $0 < \gamma \leq 1$ this indisputably leads to $\hat{\theta} \leq \theta$. Generalizing the model to cover a non-litigation period effectively lowers θ , but does not change any of Harrington's conclusions. A lower θ leads to a lower post-cartel price, as P is decreasing in θ . The intuition is the following: if a cartel member expects a low, but positive, probability of a litigation phase, optimal pricing will be slightly above the competitive price level, in order to minimize potential damages payable.

This not only supports hypothesis 1 - that post-cartel prices are expected be above the competitive equilibrium - but also leads to the formulation of the second hypothesis:

Hypothesis 2 *Post-cartel prices are expected to be higher in markets where the post-cartel period is characterized by a litigation phase.*

The above-mentioned theory by Harrington stated that the post collusive price level - given an on-going litigation phase - will be above the competitive level, as a result of the firm's individual profit maximizing behavior. Another explanation to why post-collusive might remain above the competitively predicted level is that of so-called *residual collusion*, (Harrington, 2002). Even though the cartel has ceased its collusive communication, tacit collusion might still be present (Harrington, 2004). This fourth potential explanation to post collusive pricing is investigated in the following.

2.2.4 *Residual Collusion - From Explicit to Tacit*

Residual collusion takes place when explicit collusion is replaced by tacit (Harrington, 2002). In other words, the cartel ceases to exist from a legal point of view - as the legal treatment of collusive behavior is strictly dependent on the extent of communication between the parties - but continues to operate without direct communication (Ivaldi et al., 2007). As such, the term denotes a transition from explicit to tacit collusion. The logic goes that parties that have successfully colluded previously will find it easier to coordinate and sustain some degree of tacit collusion, as elements such as trust and coordination experience enter into the relation (Leslie, 2004). The theory of residual collusion predicts that firms might be tacitly colluding in the post-cartel period, maintaining abnormal price levels in order to maximize the joint surplus of the tacit cartel. A more thorough explanation of the differences between explicit (or overt) and tacit collusion can be found in section 2.1 where a paragraph is dedicated to a discussion of these two types of collusion.

In a recent experimental paper, Fonseca & Normann (2012) find evidence that supports the hypothesis, that even after a cartel comes to an official end, residual collusion might be present accompanied with prices above the competitive level. Fonseca & Normann (2012) find evidence of a so-called *hysteresis effect* in post-cartel periods. This effect - discovered using an experimental design to investigate Bertrand oligopolies - relates to the dependence of a system on not only the present environment but also its past. In other words, they find evidence that supports that firms continue to collude successfully after communication is disabled. The research question of Fonseca & Normann (2012) is: "[w]hen and to what degree does communication help [in sustaining a cartel]?" (p. 2), and is investigated using an experimental setting, where Bertrand oligopolies with and without explicit communication are compared and the number of firms is varied. By using experimental data, Fonseca & Normann are able to determine the long-term effects of communication, including if tacit collusion is easier to sustain following a period where communication is possible.

The discovery of a hysteresis effect is only one out of four main results - however, given our research question it is by far the most interesting, and is thus the only finding described in some detail here. The other three results are: a) communication leads to higher profits in markets, regardless of the number of firms; b) collusion is easier to sustain with fewer firms, given both presence and lack of communication; and c) the gain from communicating is inversely u-shaped as a function of the number of firms. The fourth result, that of a hysteresis effect, is an indication that, following a period of collusion supported by communication, firms are able to maintain collusive prices

even when communication is not possible. This suggests that prices in post-collusive markets might remain above the competitive level.

The experimental design of Fonseca & Normann (2012) is set around a Bertrand oligopoly with constant marginal costs of zero and an inelastic demand of $m = 300$ units (up to a reservation price of 100). The good is homogeneous and the $n \in 2, 4, 6, 8$ firms set a price between 1 and 100, simultaneously and independently. The firm charging the lowest price earns a profit of $p \times m$, whereas all other firms earn nothing (in cases of ties, the winning firms split the profit). Further each of the repetitions of this game can be characterized by either *Talk* or *NoTalk*, depending on whether communication is possible or not. In cases of *Talk* the participants are able to communicate via an instant messaging tool for one minute before setting prices, while prices are set without prior communication under *NoTalk* experiments. Tests are run where *NoTalk* precedes *Talk* and vice versa. Finally experiments are also conducted where *NoTalk* is followed by *NoTalk*. In all cases the experiment was run as a repeated game with at least 20 periods. Using existing research, Fonseca & Normann establish five exploratory questions, and test these using the results of the experiment. This leads to the four main findings mentioned in the paragraph above. Due to space limitations, the set-up and findings by Fonseca & Normann will not be treated in greater detail here.¹⁰

The theory of residual collusion, combined with the findings of Fonseca & Normann, leads to the formulation of the third hypothesis:

Hypothesis 3 *Residual collusion can lead to abnormally high post-cartel prices.*

The theories of strategic pricing and residual collusion might seem similar, since both predict that price will not immediately return to a competitive level. Further, the empirical evidence for the two can resemble one another, as both theories can explain the development seen in figure 3. However, the theories are in fact fundamentally different. A major difference is that, given residual collusion, we have no expectations about prices converging to the competitive level as opposed to the theory of strategic pricing during litigation. Another fundamental difference is that in pricing strategically, each firm optimizes individually its own behavior, given that it has indirect control over the damages payable through the but-for price estimation. Thus, a Nash equilibrium is obtained where post-cartel pricing is between the competitive and the collusive price level. On the contrary, the residual collusion theory suggests that firms continue to maximize the *joint* profit of the cartel members, assuming that firms have a common interest.

¹⁰ For more information on the findings of Fonseca & Normann, the reader is referred to the original paper, Fonseca & Normann (2012).

2.2.5 Variance Variation

A number of researchers have been able to make inferences on the price variance under collusive and competitive periods, respectively. Amongst these are Athey et al. (2002), who use an infinitely repeated adverse-selection Bertrand model with cost shocks, to link price rigidity with collusion. More precisely, the authors consider a model where each firm has private information about its cost level, and where the unit cost is drawn in each period from a continuum of possible costs and the realization is i.i.d. across time and firms. The key difference from standard industrial organization models is the introduction of a changing market environment through cost fluctuations. As the derivation of the model is quite tedious, it will not be replicated here. The authors establish five main findings based on their model, whereas one is of particular interest to our research question:

"if firms are sufficiently patient [...], optimal symmetric collusion is characterized by price rigidity and the absence of price wars on the equilibrium path" (Athey et al., 2002, p. 31)

The intuition is that the lower price variance during collusive periods, *ceteris paribus*, stems from the fact that *"anytime a price change occurs in an oligopoly, there is a risk that a price war could break out"* (Carlton, 1989, pp. 914-15). As price changes lead to an increased risk of a price war, firms are reluctant to changing prices in a response to private cost fluctuations, since the signal can be misinterpreted by other firms as an attempt to diverge from the collusive agreement. Because the firms are sufficiently patient, they set the same price in every period with no response to cost fluctuations, resulting in a lower standard variation of prices during the collusive period. In other words, price rigidity in cartels prevents mistrust. This argument is supported Harrington & Chen (2006), who find that *"during the stationary [collusive] phase, price responds to cost but is much less sensitive than under non-collusion or simple monopoly"* (p. 1).

Placing these findings in a post-cartel context, I argue that a post-cartel period characterized by a non-competitive environment will, everything else equal, have lower price variation than a more competitive one. This leads to the fourth hypothesis:

Hypothesis 4 *As price variation is generally larger during competitive periods than under collusive ones, a non-competitive post-cartel period is expected to exhibit below-average price variation.*

The following section will derive and present the fifth, and last, hypothesis.

2.2.6 Reciprocity in Post-Cartel Periods

Reciprocity as a general term within social psychology refers to the behavior of responding to friendly (hostile) actions by counter-parts with friendly (hostile) actions. Reciprocity differs in a fundamental manner from cooperative and predatory conduct within repeated interactions by not being contingent on an expectation of a future material gain, (Fehr & Gächter, 2000). As a matter of fact, reciprocity can even occur at a cost to the agents who enforce it. Reciprocity can be either constructive (positive) or destructive (negative) - referring to either cooperative or retaliatory reciprocal tendencies.

While the concept is well-established within psychology, it is a fairly new strand in economics. It breaks with the classic assumption of rational economic agents - a phenomenon that can be found evidence of in much empirical research. A classic example of destructive reciprocity within economics is the ultimatum game (also known as the dictator game), in which two players have to decide on how to split an amount of money. In a collusive context, Santos-Pinto finds, in his 2007 paper *Collusion and Reciprocity in Infinitely Repeated Games*, that, under plausible perceptions of fairness, firms' preference for reciprocity facilitates collusion in infinitely repeated market games. More specifically, the critical discount rate at which collusion is sustainable is lower when firms exhibit preferences for reciprocity (Santos-Pinto, 2007). This can quite easily be shown mathematically: assume that two firms are playing an infinitely repeated Bertrand game. As is commonly known, a cartel in such a situation is sustainable if each firm prefers the discounted infinite pay-off from cooperation (l.h.s. below) over the one period gain from deviation (r.h.s. below):

$$\frac{1}{1-\delta} \times \frac{1}{2} [(p^m - c)D(p^m)] \geq (p^m - c)D(p^m) \quad (16)$$

Here p^m is the monopoly equilibrium price, defined as $p^m = \max_p (p - c)D(p)$, $D(p)$ is the level of demand, and c is the marginal cost. In the cooperative equilibrium (l.h.s.) the one-period profit is shared between the two firms, hence explaining the multiplication factor $\frac{1}{2}$, and this perpetuity is discounted to present time by multiplying with $\frac{1}{1-\delta}$, with δ being the *discount factor*.¹¹ Note that the counter-part's grim trigger strategy results in zero profits in the industry in all future periods as the game is Bertrand. Rearranging equation (16) gives the solution to δ for which the cartel is sustainable given selfish firms:

$$\delta_{p^m}^s \geq \frac{1}{2} \quad (17)$$

¹¹ Discount factor is the factor by which actors discount future payoffs relative to current payoffs. A discount factor of 1 indicates that the agent values future payoffs as much as present, whereas a discount factor of zero means that no value is placed on future values. I.e. the higher a discount factor, the more patient an agent.

If firms have preferences for reciprocity, a reciprocity term, w is added to their utility function:

$$u_i(p_i, p_j) = \pi_i(p_i, p_j) + w_i(p_j, p^f) \times \pi_j(p_i, p_j) \quad (18)$$

where $i \neq j = 1, 2$. p^f is the perceived fair price and is assumed to have p_m as upper bound and c as lower. The reciprocity term is defined as:

$$w_i(p_j, p^f) \begin{cases} > 0 & p_j > p^f \\ = 0 & p_j = p^f \\ < 0 & \text{otherwise} \end{cases} \quad (19)$$

In words the above states that firm i places a positive (negative) weight on j 's profits when j prices below (above) the fair price and no weight when price is set equal to p^f . Rearranging (18) yields $\delta_{p_m}^r \geq \frac{1}{2} - w$. As $w(p^m, p^f) \geq 0$ it follows that:

$$\delta_{p_m}^r > \frac{1}{2} - w(p^m, p^d) \geq \delta_{p_m}^s \quad (20)$$

Therefore, preferences for reciprocity always facilitate collusion, given an infinitely repeated Bertrand duopoly.

The same result can be obtained, given similar assumptions, under Cournot competition (Santos-Pinto, 2007). In a more recent paper, Iris & Santos-Pinto (2013) arrive at the same conclusion, modelling the situation as a dynamic game. They conclude "*that collusion is easier to sustain when firms have a concern for reciprocity towards competing firms provided that they consider collusive prices to be kind and punishment prices to be unkind*" (p. 50).

An alternative approach to reciprocity in cartels, is to regard the collusive agreement as a so-called *incomplete contract*. The incompleteness stems from two facts; first, the contingencies are not formalized, as very few cartels are documented due to their illegality; and second, the contract is not enforceable. Using labor contracts in an experimental setting, Fehr, Gächter and Kirchsteiger (1997) show that reciprocity substantially contributes to the enforcement of contracts. This reasoning supports the argument that reciprocity is a factor in sustaining collusion. Even though it will not be explored in further detail here, the treatment of cartels as incomplete contracts is an interesting area for future research.

As reciprocity is proven to be an important facilitator of collusion, there is no reason to believe that it loses its importance following a cartel breakdown. This leads to the formulation of the fifth, and last, hypothesis:

Hypothesis 5 *Due to reciprocity, post-cartel periods triggered by whistle blowing or deviation from an agreement, are expected to be characterized by above-average competition.*

2.3 SYNTHESIZATION OF FINDINGS

The above analysis has led to the development of five hypotheses on how post-cartel prices can be expected to develop.

The five hypotheses derived above, that will be the point of departure in the empirical analysis, are as follows:

1. Given non-efficient markets, the immediate post-cartel prices are expected to be above the competitive level
2. Post-cartel prices are expected to be higher in markets where the post-cartel period is characterized by a litigation phase
3. Residual collusion can lead to abnormally high post-cartel prices
4. As price variance is generally larger during competitive periods than under collusive ones, a non-competitive post-cartel period is expected to exhibit below-average price variation
5. Due to reciprocity, post-cartel periods triggered by whistle-blowing or deviation from an agreement, are expected to be characterized by above-average competition

EMPIRICAL ANALYSIS

Chapter 2 presented a theoretical approach to the problem of price developments in the post-cartel period. It addressed the question of how, from an economic point of view, prices can be expected to develop. Taking the theoretical predictions from chapter 2 as point of departure, this chapter is devoted to an empirical analysis of post-cartel prices. This part will use both existing and original empirical work to test the theoretically derived hypotheses.

As an empirical test of some of the hypotheses demands a significant amount of data - and since cartel data is notoriously difficult to obtain - it has, alas, not been possible to test all five hypotheses empirically. Where a direct empirical test of a hypothesis has not been possible, I will give recommendations as to how this could be done if in possession of the required data.

First, this chapter will present existing empirical research that supports or opposes the five hypotheses. Second, the analysis design will be laid out. Third, the empirical methodology to support the analysis will be presented and discussed. Fourth, the empirical analysis itself will be described. Finally the results will be presented and discussed, and recommendations on how to test the remaining hypotheses will be given.

3.1 EXISTING EMPIRICAL RESEARCH

As is evident from both the introduction and the theoretical analysis, not much research exists in the area of post-collusive pricing. This is also the case for research of more empirical nature. In the following, the most relevant known empirical research related to the five hypotheses will be presented.

Erutku (2012) tests *hypothesis 2*, that prices are higher in post-cartel periods characterized by a litigation phase. Using Harrington's (2004) measure for strategic pricing bias, Erutku investigates a retail gasoline cartel in the province of Quebec in Canada, and asks the question: "*could price decreases have been larger, i.e. did conspiring firms strategically set post-cartel prices to reduce the damages they would have to pay?*" (p. 340). Erutku does this by estimating the bias, as presented in equation (12), with the reduced form:

$$\frac{p_t^* - \hat{p}_t}{\hat{p}_t} = \beta_0 + \beta_1 X_t + \beta_2 n_t + \beta_3 Z_t + \eta_t \quad (21)$$

He further formulates that, if firms are behaving as predicted by Harrington (2004) in the post-cartel period, $\beta_1 > 0$ if X_t raises the prob-

ability of damage payments, and $\beta_1 < 0$ if the variable in X_t corresponds to damage payments. Recall that Harrington's prediction is that conspirators set a higher price than the non-collusive in the post-cartel period, in order to minimize damages payable. Remember also that the bias between the strategic and non-strategic price increases when firms put more weight on damages and falls after sentencing. Eruktu findings support some of Harrington (2004)'s claims; the bias decreases with time and increases with the filing of charges. However, as he points out, although the "*finding is coherent with Harrington (2004)'s theory of strategic pricing during litigation [...] residual collusion (whereby explicit collusion might have been replaced by tacit collusion) cannot be ruled out*" (Eruktu, 2012, p. 342).

At least two papers are known to have tested *hypothesis 4* (price variance) empirically; Abrantes-Metz et al. (2006) and Bolotova et al. (2008). Abrantes-Metz et al. (2006) very concisely deals with the issue of variance variation. The authors set out to identify a data screen for anticompetitive conspiracies, and find that low price variation in a market may indicate the presence of collusive conduct. They examine how the first two moments of the price distribution develop over time, around the collapse of a bid-rigging conspiracy. They find evidence that the price mean *decreases*, while the standard deviation *increases*, following a transition from a collusive to a post-collusive environment. By investigating the case of retail gasoline in Louisville from 1996 to 2002, Abrantes-Metz et al. find that prices decreased by 16 % while the standard deviation of price increased by 263 % following the collapse of the cartel. This finding empirically supports the hypothesis that prices during collusive periods is more rigid than during competitive periods.

Another central paper in the empirical literature on the topic of price variation under collusion is Bolotova et al. (2008). Using ARCH and GARCH models, the authors examine the impact of the lysine and citric acid cartels on price level and variance simultaneously. They find that during the lysine cartel, both the first and second moment are higher than during the competitive period. However, in the case of the citric acid cartel, prices are higher in the collusive than during the competitive period, but the price variance is lower. Nonetheless, this deviation from the expected result does not refrain the authors from arguing that in general "*an increase in the mean price and a decrease in the price variance may indicate the presence of collusive conduct in markets*", (Bolotova et al., 2008, p. 1304).

Even though an increasing number of studies point towards reciprocity being a sustaining factor in collusion, *hypothesis 5*, this does not appear to have been tested empirically hitherto. This might be related to the fact that reciprocity in general is difficult to test in a non-experimental setting. However, as will become evident later in

this section, there are other ways of testing reciprocity in collusive behavior.

Above, the reader has been presented some of the (few) empirical studies into post-collusive pricing. The following section will be discussing how the five hypotheses can be tested in an empirical setting.

3.2 ANALYSIS DESIGN: HOW TO TEST THE HYPOTHESES

The most optimal approach would be to establish an analysis design, based on one single data set, that could test all five hypotheses. The main constraint in doing so is to identify a valid, reliable and *available* cross-sectional data set, including information on prices and quantities over a long period of time. Not only is cartel data per definition difficult to obtain, it also requires a large set of cross-sectional data, complicating the task even further.

Alas, it has not been possible to obtain a comprehensive and elaborate data set over a large number of cartels, including both prices and quantities. Therefore, in the following I will give guidance to where to potentially find such a data set. As a second-best, the thesis will proceed with an analysis of a single case where data is publicly available, and one of the hypotheses on this case. Finally, recommendations will be given as to how the remaining hypotheses could be empirically tested.

3.2.1 *An Optimal Data-set: 13 Chemical Cartels*

It is the belief of this author that a cross-sectional data set, spanning over a significant number of cartels - preferably more than 10 - with information on cartel characteristics¹, market price and quantities produced (before, during, and after the cartel), will allow the researcher to carry out an empirical analysis of at least four of the five hypotheses. That is, hypothesis 1, 2, 4, and 5, as hypothesis 3 - dealing with residual collusion - is found to be very difficult, if not impossible, to test empirically. Preferably the markets under scrutiny should be characterized by a homogeneous product, allowing for comparison of publicly observable prices. Finally, the cartels should not be too recent, as a short post-cartel period makes it difficult to reliably measure and compare post-cartel prices.

By basing the analysis on such a data set, it would be possible to identify differences in post-cartel behavior which can, in turn, be attributed certain cartel characteristics, such as cartel termination. For example, finding that post-cartel prices on average are lower in cartels that were terminated as a result of whistle blowing rather than coming to an end as a result of a mutual agreement, can be inter-

¹ Such as duration, number of conspirators, how it came to an end, etc.

preted as a support to hypothesis 5. In the following, the reader will be taken through a data set that is believed to fulfil the requirements listed above, but which is unfortunately not publicly available at the moment.

A good source for obtaining reliable, comprehensive and relatively available information on cartels, is the European Commission (EC). Thus, the first data selection criterion imposed is that the EC has conducted a study on suspected cartels and that this is announced in their official communications. In appendix [A.2](#) the reader can find information on cartel cases retrieved from the EC's homepage, listing 108 cases - either on-going, completed or dismissed - during the period 2001 to April 2014. Since a study would focus on the price effects of cartels, the sample will be limited to those cases where the companies under scrutiny have been found guilty and a penalty has been imposed. Further, the data sample used in the analysis should exclusively include cartel cases that have been concluded before 2011, in order to allow conspirators a chance to appeal, as well as to ensure that the process of potential private litigation have run it's course. This limits the time period to 2001-2010.

The next limitation on the data is that the cartel under scrutiny must be terminated before 2003. This requirement comes from the need for a post-cartel period, in order to be able to investigate the price developments following cartel convictions. Having a post-cartel period of approximately 10 years, allows for a thorough analysis of the post-cartel price developments. Cartels that continued to exist after 2003 can therefore hardly be part of the sample. Note that there can be, and often is, a difference between the end of the cartel (which marks the beginning of the post-cartel period) and the discovery of the cartel.

Among the cases remaining in the sample are cases involving markets with very different characteristics. In order to allow for an investigation of the price developments, it is essential that comparable price information is available before, during and after the cartel. This excludes markets where prices are determined by negotiations between buyers and sellers, as in the case of (38240) Industrial tubes, (37956) Concrete reinforcing bar and (38907) Steel beams. Pricing information is difficult to obtain in markets with a high degree of product differentiation, as well as in markets too small to warrant any third-party price information collection. Examples of these are (38823) Elevators and Escalators, (38338) Needles, (38359) Electrical and mechanical carbon and graphite products and (38354) Industrial bags.

In general, the sample should be limited to those cases with a relatively homogeneous product and where pricing information is likely to be available. Such a subset, are those in the markets of chemical substances and derivatives - in this definition is also be included organic compounds such as vitamins. This narrows down the data sam-

ple to cartel cases with EC NACE code:² C.20 (Manufacture of chemicals and chemical products), C.21 (Manufacture of basic pharmaceutical products and pharmaceutical preparations), and C.22 (Manufacture of rubber and plastic products).

The choice of the chemical industry as subset can be explained by a number of reasons. First, chemical cartels constitutes a significant share of cartels uncovered by the EC throughout time. Amongst all cartel investigations initiated by the EC between 2001 and 2010, one out of three were in a market for a chemical product. This is obviously much larger than the industry's contribution to GDP in the European Economic Area (Eurostat, 2014), and this discrepancy can be explained in two ways. One explanation could be that chemical cartels are less effective than the average cartel, and are therefore uncovered by anti-trust authorities more easily - a hypothesis that does not seem to be supported by any theory nor empirical finding. Another explanation could be that chemical markets exhibit a specific set of characteristics that makes them more suitable for collusive behavior. Hay & Kelley (1974) find that "*conspiracy among competitors may arise in a number of situations but it is most likely to occur and endure when numbers are small, concentration is high and the product is homogeneous.*" (pp. 26-27). This is, not surprisingly, the case of the chemical industry, which is mostly characterized by few players on the market and relatively - if not fully - homogeneous products. A third feature that makes the industry well-suited for an analysis of the post-cartel price developments (but is not proven to affect the collusive tendencies) is the fact list prices on chemicals are somewhat accessible in the public domain.

By applying the above-mentioned criteria to the original 108 cases in appendix A.2, we arrive at a preliminary sample of 25 cartels³ within various chemical markets, which ceased illegal operations before 2003 and were fined between 2001 and 2010.

The next step in the data selection process is of a more qualitative character. Not all of the remaining 25 cartel cases are found suitable, when analyzing the post-cartel price developments. A number of qualitative requirements should thus be imposed: (a) the cartel product must be a clearly defined single chemical, and not a group or category of chemicals, such as (38589) Heat stabilisers, (36700) Industrial and medical gases and (37671) Food flavour enhancers; (b) the product should not be a rubber (e.g. (38443) Rubber chemicals and (38638) Synthetic rubber) or petroleum related ((38456) Bitumen Nederland). Such selection criteria are not believed to create a further bias in the data sample, as there is no reason to believe that cartels

² NACE Code is a pan-European classification system which groups organisations according to their business activities.

³ For a list of all 25 cartels, please refer to appendix A.2. In this figure, the vitamin cartel is treated as one, even though collusion took place in 12 different vitamin markets.

in these areas should have behaved differently from the rest of the preliminary sample of 25. However, as pointed out earlier, the data might already be heavily biased due to the selection bias when working with cartel samples.

The final selection criterion of more simple character, and is related to neither the nature of the cartel nor the market or product. This criterion is that sufficient pricing data is available. Some markets are large, while others are relatively small, with only a few suppliers and no third party price monitors, such as a trade journal. This might impose another bias on the data, since smaller markets might be excluded from the sample.

In total there are 12 cases from the EC, which should be included in this data set. Furthermore, the Lysine cartel - which was fined by the American Department of Justice, not the European Commission - can be included, as the investigation ended shortly before 2001 (more specifically in 2000), and much research has already been carried out on this cartel, allowing for easy access to information such as pricing data.

This selection process leads to a subset consisting of the cartels listed below, with, in first parenthesis, year of final decision and in second total administrative fine imposed. This subset - if available - would provide a solid starting point for an empirical analysis of post-cartel pricing. In the below list, the first number is the EC code, the year in parenthesis the year of final decision, and the amount in second parenthesis the total administrative fine imposed.

Cases to include

- 38645 (2006) Methacrylate (EUR344m)
- 38620 (2006) Hydrogen peroxide (EUR388m)
- 37773 (2005) Monochloroacetic Acid (EUR216m)
- 37533 (2004) Choline chloride (EUR66m)
- 37857 (2003) Organic peroxide (EUR72m)
- 37370 (2003) Sorbates (EUR138m)
- 37978 (2002) Methylglucamine (EUR3m)
- 37519 (2002) Methionine (EUR127m)
- 37027 (2001) Zinc phosphate (EUR12m)
- 36604 (2001) Citric Acid (EUR135m)
- 37512 (2001) Vitamins (EUR855m)
- 36756 (2001) Sodium gluconate (EUR37m)
- (2000) Lysine

3.2.2 *Analysis Design: A Single Case*

As the analysis of a larger sample of cartel cases is not feasible, let us turn to the analysis of a single case. It is evident that the binding constraint is data availability, as data is not easily obtained in research on cartels. An alternative approach that will be pursued here, is to assess post-cartel prices in a single cartel case. On the one hand, this approach makes data collection easier, but on the other it lowers the external validity and generalizability of the findings. Further, a non-cross-sectional data set prohibits a comparison across cartels and thus limits the analysis and the ability to test the five hypotheses. Thus, analyzing a single case allows for an empirical test of primarily hypothesis 1 and partly hypothesis 4. The remaining three hypotheses will therefore not be directly tested here.

A cartel case in which sufficient data is publicly available is that of the German cement cartel during the 1990s. Note that this cartel is not included in the above list of 13 cartels, as the cartel was prosecuted only by the German anti-trust authorities and not the European Commission. Both data on prices and production is accessible through the Federal Statistical Office of Germany (DESTATIS). Further, the cartel has already been subject to academic research, which will ease the analysis, through increased understanding the cartel (Hüschelrath et al., 2008; Frank & Schleiffke, 2013). Finally, as the cartel was initiated in the beginning of the 90s and ceased its collusive conduct in the beginning of the new millennium, it fulfils two essential requirements for conducting a post-cartel pricing analysis; first, because it ended in 2001, there is room for a sufficient post-cartel period to analyze; and second, by beginning in the early 90's, it seems plausible that reliable data is available for the pre-cartel period. In sum, the German cement cartel constitutes a good case on paper for a post-cartel pricing analysis, and will therefore be used to assess the validity of (some of) the five theoretical hypotheses.

From a methodological perspective, two general approaches are available for the purpose of this analysis; a structural or a non-structural econometric model. These different approaches will be presented and discussed in detail in the following section. In this analysis, a structural econometric model, the conduct parameter method (CPM), will be used. The procedure will, to a large extent, follow that by Genesove & Mullin (1998), with the exception that no direct cost measures are available in the present analysis. The CPM imposes strict assumptions on functional forms, but is chosen primarily as the data requirements are relatively simple. Without going into the details of the methodology, as this is left for the following section, using the CPM allows us to establish a measure for the degree of competition in a given market. Estimating this individually for the pre-cartel, cartel, and post-cartel periods allows for a comparison of competition intensity.

The objective of this analysis is to estimate the degree of competition in the pre-cartel, cartel and post-cartel markets, respectively, through the conduct parameter. *Ceteris paribus*, assuming no structural market changes, a higher conduct parameter in the post-cartel period than in the pre-cartel period can be seen as a support of hypothesis 1. Moreover, this part is meant as a guideline as to how an analysis of a larger data sample would be carried out, if the necessary data had been available.

As mentioned above, a number of methodological approaches can be applied, in order to evaluate post-cartel price developments. In order to substantiate the choice of method, the following section will review a selection of different approaches, and argue why the conduct parameter method is chosen.

3.3 EMPIRICAL METHODOLOGY

In this section, two different methods useful to evaluate the post-cartel price developments will be reviewed; *but-for price* estimation and *conduct parameter* estimation.

The but-for price approach is widely used in practice such as in damage estimations during litigation, and can be categorized as a *descriptive* or *non-structural econometric model*. Such models do not rely explicitly on formal economic theory. The second method, the conduct parameter estimation, falls in the category of *structural econometric modelling*. These models rely on explicit economic theory, which is used to derive formal expressions about mathematical relations between variables - often by imposing strict functional forms. In sum, structural econometric models combine explicit economic theories with statistical models, as opposed to non-structural or descriptive econometric models, which are commonly used when there is no or little economic theory available (Reiss & Wolak, 2007).

First, the non-structural estimation method will be reviewed. Second, a structural approach is presented - the conduct parameter method. As the latter is based on formal economic theory, the review will be largely theoretical - as such, section 3.3.2 deviates by not only being a methodological discussion, but to a great extent includes theoretical considerations and derivations. Finally, the two methods are compared and discussed.

On a side note, it is worth mentioning that these are only two out of many approaches to identify how prices could have developed in the post-cartel period. However, as will be discussed later on, both methods have several appealing characteristics that makes them suitable for the present analysis.

3.3.1 *Non-structural Econometric Models*

In order to determine if post-cartel prices are above the level they "would have been" if not for the cartel, a commonly used procedure is to estimate the so-called *but-for price* - the price that would have prevailed, but for the cartel. Such an estimation falls within the category of counter-factual analysis, as this hypothetical situation cannot be observed. This leads to the area often being subject to a significant amount of discussion, as there is no "true" value of the but-for price. It is worth noting that these methods are mostly and widely used in the field when estimating cartel overcharges - that is, the total amount above the competitive equilibrium price paid by customers - and thus damages payable in civil lawsuits. As stated by the EC, "[c]ompensation for harm suffered aims to place the injured party in the position in which it would have been had the infringement of Article 101 or 102 TFEU not occurred" (European Commission, 2011, p. 8).

The so-called comparator-based method is a term used to cover a number of approaches to determine a but-for price. The general idea is to use a comparable market as a proxy for how prices in the cartel period would have developed but for the collusive behavior. Finkelstein & Levenbach (1983) provide a useful insight into the practical use of the but-for method, by reviewing four cartel cases and the regression analyses that were used in court proceedings to estimate the overcharge of the cartel.

Four different approaches within the comparator-based method are dominantly used (European Commission, 2011): a) Comparison over time on the same market; b) Comparison with data from other geographic markets; c) Comparison with data from other product markets; and d) Combining comparisons over time and across markets. These four approaches will be treated briefly in the following, with an emphasis on procedure as well as benefits and pitfalls related to each method.

COMPARISON OVER TIME ON THE SAME MARKET The comparison over time on the same market is also known as the *before-and-after* or the *benchmark* approach, and is one of the most widely applied methods when estimating the but-for price. The overall idea is to use the time before and/or after the infringement period as an indicator of how the price should have developed during the cartel period.

The main advantage of this approach is that market characteristics may be easily compared. However, when analyzing the but-for price in markets where a cartel has been present for longer period of time, such as that of organic peroxide (EC case COMP/E-2/37.857) initiated in 1971, pre-period data is very likely obsolete as a predictor of the but-for price in the 90s.

One of the most significant complications when using the before-and-after approach is the determination of the infringement period, i.e. the beginning and end of the infringement. The cartel duration affects the estimation of the but-for price since data from non-collusive periods are used to estimate the but-for price during the cartel period. Including part of the collusive period in the non-collusive estimator period can lead to an over-estimate of the but-for price, and vice versa. In general, the termination of a cartel is easier to determine than the beginning, as the end is normally characterized by a more dramatic event by comparison to the multiple events leading up to the beginning (European Commission, 2011). Thus, estimation of both the cartel commencement and termination plays an important role in the analysis.

Harrington (2004) finds that including the pre-cartel period when estimating the but-for price can lead to an overestimate of the overcharges, as discussed in section 2.2.3. On a practical note, Harrington therefore recommends a number of options to deal with this problem. Amongst those, one proposed solution is to exclude the post-cartel data from the market under investigation. However, it must be noted that, such an approach is not without pitfalls.⁴ Harrington brings up another potential bias when applying this method. An increased price pattern following a cartel formation might be a response to abnormally intense competition - implying low prices - in the short term in the pre-cartel period.⁵ If this is the case, the pre-cartel data might not be a valid indicator for the price that would have prevailed in a competitive market in the long term, but for the existence of the cartel.

COMPARISON WITH DATA FROM OTHER GEOGRAPHIC MARKETS
A second comparator-based approach is to use pricing data from another geographic market of the same product. If a cartel only fixed and raised prices of chemical A in the US market for example, the European market could be used when estimating the non-collusive equilibrium price. A high similarity between the two markets increases the precision of the one market as a predictor of the other. Obviously, the approach is however only applicable when the cartels are not extending worldwide - or have a global impact on price levels. Further, it might not always be possible to determine the geographic extent of the cartel with certainty. Markets might be inter-related and overlapping, resulting in collusive effects diffusing into other geographic regions.

⁴ For more on these potential pitfalls, see section on policy analysis in Harrington (2004) for a more elaborate discussion.

⁵ An example of abnormally intense competition might be the citric acid case; during the 18 months prior to the cartel formation prices fell from 80 cents to 60 cents per pound. During the first 18 months of the cartel prices increased to 80 cents per pound again (Connor, 2000).

A restriction on this approach is that the comparator market should optimally not have been under any infringement during the period of time used for comparison. This poses a falsifiability problem, as "no number of confirming observations can verify a universal generalization".⁶ In other words, it is never possible to determine with certainty that a market has not been subject to price fixing or other collusive behavior. The fact that a cartel has not been exposed in a market, does certainly not imply that no collusive behavior has been present. Whereas this problem is relevant in all the methods discussed here, it might pose a more significant problem when comparing with other geographic markets or other product markets.⁷

COMPARISON WITH DATA FROM OTHER PRODUCT MARKETS A third method to estimate the but-for price in the market under scrutiny is to compare the price development with that of a similar - yet different - product market. For example if the markets for chemical A and B share many common characteristics (this could be inputs, customers, manufacturers, end-use, etc.), market B might be used as a comparator when trying to estimate the but-for price in the market for chemical A.

This approach shares many of the benefits, pitfalls and biases with the geographical comparison discussed above. It might not always be possible to identify a suitable comparable product market. And if it is possible to identify one, there is always the risk that closely similar product markets might not only share "beneficial" characteristics for the analysis, but might also have been directly affected by the collusive behavior in the infringement market. In this case the comparable market might not be a good proxy for an estimation of a but-for price.

COMBINING COMPARISONS OVER TIME AND ACROSS MARKETS The fourth, and last, comparator-based method, is a combination of the three approaches presented above. It is also known as the *difference-in-differences* method, since it measures the difference between differences over time - i.e. the difference in price over time in both the collusive and the non-collusive market. The benefit of this approach is that it isolates the effect of the collusive behavior, in a more elaborate manner than the simpler methods. A price increase during an infringement period might be only partly due to collusive behavior, while another part for example can be explained by an in-

6 Popper, K. R. (1994). *Two meanings of falsifiability*. In Seiffert, H.; Radnitzky, G. Handlexikon der Wissenschaftstheorie. München: Deutscher Taschenbuch Verlag. pp. 82-85.

7 One could argue that it is never certain that no cartel has been present in the pre or post-cartel markets, when doing comparison over time on the same market. It is indeed a relevant argument, as the beginning and end of the cartel is normally difficult to determine. However in such case, it is my argument, that the researcher is normally aware of the potential problem, and thus more vigilant than when using another geographic or product market.

creased cost of inputs. Such a situation can be captured by using a comparable market and the difference-in-differences method. The method however strongly relies on the assumption that these exogenous changes affect both markets similarly (European Commission, 2011).

The above paragraphs gave an introduction to the non-structural econometric models. The following section will introduce the reader to structural econometric models.

3.3.2 *Structural Econometric Models*

This section is not meant to give a full-fledged review of structural econometric models, but to give a brief introduction to concept as a whole. Econometric models that rely on explicit economic theories are known as *structural econometric models*. The idea is that economic theory is used to develop mathematical statements about how a set of observable endogenous variables depend on both a set of observable exogenous variables as well as a set of unobservable variables. Such models are normally used when there is a significant amount of relevant economic theory available, as opposed to situations with little. In the latter case, researchers will in general be better off using *descriptive* or *non-structural econometric models* such as the comparator-based methods discussed above (Reiss & Wolak, 2007).

Structural econometric models are a useful tool in the present analysis, primarily due to two reasons. First, they can be used to estimate unobservable parameters that could otherwise not be inferred from non-experimental data. Second, the models are generally useful when conducting counter-factual analysis, such as in the present case (Reiss & Wolak, 2007).

Structural econometric models are applied in a wide variety of areas within industrial organization (IO) including analyses of market power, allocation mechanisms and game theory. For this analysis, the assessment of market power is used to evaluate how post-cartel pricing compares to pre-cartel and collusive pricing. The procedure is as follows: an estimation of market power, here the conduct parameter, can be used as a proxy for overcharges and cartel price-behavior. The analysis will reveal how the conduct parameter have developed during pre-cartel, cartel and post-cartel periods, respectively. A statistically higher conduct parameter in the post-period than in the pre-period, across the sample, could indicate that post-cartel prices do not stem from a competitive equilibrium, but are a result of some sort of off-equilibrium behavior (residual collusion, strategic pricing during litigation, etc.) *ceteris paribus*. Finally, estimates of the pre-cartel conduct parameter can be used to establish the counter-factual but-for prices, that could have been expected to prevail during and after the cartel.

There is, to my best knowledge, currently no academic papers using this approach in order to analyze post-cartel prices generally.

For a thorough review of structural econometric modeling, the interested reader can refer to Reiss & Wolak (2007). The next section will present one structural econometric model, that is the conduct parameter method.

3.3.2.1 *The Conduct Parameter Method*

The following review of the *conduct parameter method* (CPM) is based on the framework developed by Brasnahan (1982, 1989) and Lau (1981) and applied in Genesove & Mullin (1998), amongst others. This econometric model is rooted in economic and IO theory and allows the researcher to indirectly infer market conduct and unknown cost parameters, using only the responsiveness of price to changes in demand elasticities and cost components (Genesove & Mullin, 1998). Data availability - or more specifically the lack of "good" data - has always been a challenge to IO researchers. In that sense, the conduct parameter framework offers an intuitive and compelling method, as it only requires data on price and output.

The approach is part of what Bresnahan (1989) dubbed *New Empirical Industrial Organization* (NEIO), and was symbolized a break with the *structure-conduct-performance* approach (Bain, 1951). This method, laid out by Bain in the 1950s, used cross-sectional data to regress accounting measures of profits and costs - an approach that was not without pitfalls, as such accounting measures are not always economically meaningful (Einav & Levin, 2010).

While Brasnahan (1982) and Lau (1982) laid the theoretical foundations for the NEIO with the conduct parameter framework, Genesove & Mullin, in their 1998 paper on the American sugar cartel of the late 1890s, showed that the method indirectly predicts demand and costs well, when comparing estimates with direct measures.

The fact that both the chemical industry markets as well as the cement market all are homogeneous to a high degree simplifies the analysis. That being said, a conduct parameter analysis can also be carried out in industries with heterogeneous product.⁸ However, as the optimal data sample as well as the cement cartel is chosen partly based on the homogeneity of the products, the treatment of market power in heterogeneous markets will not be dealt with here. The interested reader is referred to Bresnahan (1989) for a discussion of conduct parameter estimation in heterogeneous markets. The following establishment of the model is based on Bresnahan (1982).

⁸ Bresnahan (1989) discusses potential methods to deal with heterogeneity in section 4 of his paper

THE MODEL We start out by assuming that the demand function is of the following form:

$$Q = D(P, Y, \alpha) + \epsilon \quad (22)$$

As can be seen in (22), the quantity (Q) is expected to be a function of price (P), an exogenous variable (Y) and the parameters (α) which we wish to estimate. ϵ is the econometric error term.

On the supply side, the relation is less straight-forward. Under perfect competition (or in a Bertrand oligopoly), where sellers are price-takers, the pricing rule is $P = MC$:

$$P = c(Q, W, \beta) + \eta \quad (23)$$

Here W is an exogenous variable while β is the parameters to be estimated. η is the econometric error term.

On the contrary, if the industry is characterized by monopoly pricing, perceived marginal revenue will be equal to marginal cost. More generally one can write:

$$P = c(Q, W, \beta) - \theta \times h(Q, Y, \alpha) + \eta \quad (24)$$

Equation (24) needs some explanation in detail. In general it states that the supply price depends on marginal cost, $c(\bullet)$, as well as a mark-up. $P + \theta \times h(\bullet)$ or $P + \theta QP'(Q)$ is the so-called *perceived marginal revenue* (MR). The newly introduced term θ is the central element in this model. It is an indicator of the *degree of market power* or *conduct parameter*, which can take any value between zero and one. For $\theta = 0$ the second term on the right hand side of (24) equals zero, and the expression is collapsed to equal that under Bertrand oligopoly - or full competition - that is $P = MC$. On the other hand, if $\theta = 1$, pricing is determined as in a monopoly ($MR = MC$). All other values of θ between zero and one represent various oligopoly solutions, where one of these is the classic Cournot oligopoly equilibrium where $\theta = \frac{1}{n}$. Thus, the model combines the three standard models - Cournot, Bertrand and monopoly - in one supply relation. In other words, the parameter θ gives an indication of the market power, i.e. the ability to price above marginal cost.

This approach to the supply relation is derived from the conjectural variations model, where oligopoly firms shape expectations about rivals' aggregate output, and defines a best response to each given output level. If each firm i anticipates that rivals' aggregate output is a function of i 's output $R_i(q_i)$ and $R_i'(q_i) = r_i$, the first order condition of firm i is $P = c_i'(q_i) - (1 + r_i)P'(Q)q_i$ - which is equal to (24) when $1 + r_i = \theta$ (Corts, 1999).

Returning to the model specification, the econometricians' task is now to estimate (22) and (24) simultaneously in a two-stage least squares regression, with Q and P being the endogenous variables in

both equations - that is, two equations with two unknowns. The question is now whether θ is identified, i.e. if a competitive and a collusive equilibrium are observationally distinct. To proceed we assume linear demand and marginal cost functions. These can be written quite straightforward as:

$$Q = \alpha_0 + \alpha_1 P + \alpha_2 Y + \epsilon \tag{25}$$

$$MC = \beta_0 + \beta_1 Q + \beta_2 W \tag{26}$$

By substituting in marginal revenue and the cost function, as defined in 26, the supply equation from (24) can be re-written as:

$$P = c(\bullet) - \theta h(\bullet) + \eta = \beta_0 + \beta_1 Q + \beta_2 W - \theta \frac{Q}{\alpha_1} \tag{27}$$

The steps that follow are explained the easiest using a graphical argument. In figure 4, the left-side graph shows the problem that arises when attempting to determine if an equilibrium is a result of either $P = MC$ or $MR = MC$. As is evident, the point denoted E_1 is the equilibrium of two different pricing regimes: one is the competitive with demand D_1 and marginal costs MC^c ; the other is the monopoly with demand D_1 and marginal costs MC^m . Thus, with the current set-up where the demand is shifted by an exogenous variable Y , identification of the conduct parameter θ is not unique.

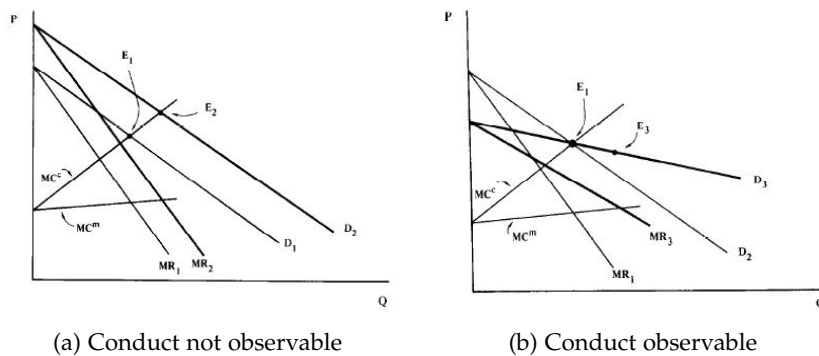


Figure 4: Conduct parameter identification. Source: Bresnahan (1982)

In order to be able to separate the competitive and collusive market structures that yield the same price-output equilibrium, we generalize the demand function, allowing exogenous variables to shift the slope of the demand function. In graphical terms this means that the demand curve is rotated around E_1 instead of only shifting it vertically. Such a rotation maintains the competitive equilibrium in E_1 but changes the monopolistic equilibrium, hence making separability observable.

The generalized demand function is:

$$Q = \alpha_0 + \alpha_1 P + \alpha_2 Y + \alpha_3 P \times Z + \alpha_4 Z + \epsilon \tag{28}$$

Here Z is a new demand-side exogenous variable that enters the equation by itself and as an interaction term with price, resulting in both rotation and shifts of the demand curve. In order to introduce some intuition, Z can be interpreted as the price of a substitute good, while Y can be interpreted as income. As can be seen in the right side of figure 4, demand is now rotated around E_1 to get $D_3 - MR_3$. If MC^c is the marginal cost curve, and competition is perfect, this should have no effect on the equilibrium, which will remain in E_1 . If, however, supply was under monopoly, the equilibrium shifts to E_3 , where $MR_3 = MC^m$. Thus, by introducing an interaction term allowing demand to both shift *and* rotate, the hypotheses of monopoly and competition are observationally distinct.

Combining the generalized demand function from (28) with the supply curve in (24) yields the new supply relation:

$$P = \beta_0 + \beta_1 Q + \beta_2 W - \frac{\theta}{\alpha_1 + \alpha_3 Z} Q + \eta \quad (29)$$

Which can be re-written by defining $Q^* = -\frac{Q}{\alpha_1 + \alpha_3 Z}$

$$P = \theta Q^* + \beta_0 + \beta_1 Q + \beta_2 W + \eta \quad (30)$$

Two exogenous variables are included, Q and Q^* , and two are excluded, Z and W . Therefore, θ is identified as the parameter to Q^* .

Let us take a step back, and summarize what has been learnt so far. The method described above has introduced the conduct parameter, which measures the competitiveness of a market and places it on a continuum between perfect competition and monopoly. The conduct parameter can be interpreted as the elasticity-adjusted Lerner Index⁹, that is as measure of the divergence of prices and marginal costs (Genesove & Mullin, 1998). The fact that it is a structural econometric model imposes a number of assumptions on the functional forms of the demand and cost functions. One important feature is that it measures the above-cost pricing simply by inferring the marginal costs, which are not directly observable. The analysis is relatively easy to apply if the researcher: (a) is in possession of price and output data; (b) can make reasonable assumptions on the functional forms of demand and costs; and (c) is investigating a market with homogeneous goods. The simplicity of the method as well as the relatively undemanding data requirements, have made the model popular amongst empirical IO researchers.

Next the applicability of the method will be discussed, and a review of some the critique of the model that has been raised will be presented.

⁹ The measure is normalized by the price-level (as all Lerner indices) as well as demand elasticity in order to distinguish markets with high margins due to inelastic demand and collusive behavior, respectively.

DISCUSSION AND CRITIQUE The conduct parameter model has been criticized for imposing too strict assumptions on the functional forms of demand and costs. Erroneous assumptions on the function forms might lead to incorrect estimates of demand and market conduct. An important critique is found in Corts (1999), which argues that the conduct parameter fails to measure market power accurately, especially under dynamic oligopolies. Static and dynamic oligopolies differ in that, in the former, profits are maximized in each period without explicit consideration of other periods, while in the latter includes the behavior of competitors in other periods than the current. As such, dynamic oligopolies allow for cartel members to punish deviations from price or output agreements, e.g. by imposing a lower profit "punishment" outcome (Puller, 2006). Corts uses well-behaved data generated by tacit collusion and supported by repeated interaction, to show that conduct parameter estimates of market power can be seriously misleading. As pointed out by Corts, the conduct parameter method can be seen as comprising of two steps: first, the slope of the supply relation is estimated, in order to measure the *equilibrium variation*; second, this variation is mapped into the inferred *equilibrium value* of the price-cost margin. Corts' critique is related to the latter step and he argues that the approach, relying on the conjectural variations model, is fundamentally flawed. As Corts' proof is somewhat lengthy, it will not be repeated here. The interested reader is referred to the original paper from 1999.

A response to the Corts critique is found in Puller (2006). Puller derives a general empirical model that takes imperfect collusion into account, which was a significant part of the Corts critique. Puller does so by including an additional term in the maximizing joint profit first order condition, a term that incorporates an incentive compatibility constraint for firms to remain in the collusive regime. In Puller's model firms in a static oligopoly behaves as prescribed by (24). However, firms in a dynamic oligopoly choose the joint quantity to maximize joint profit subject to an incentive constraint.

$$\max \sum_{i=1}^N \pi_{it} \left(\frac{Q_t}{N} \right) \quad \text{s.t.} \quad (31)$$

$$\pi_{it}^{\text{br}}(Q_t) + \sum_{s=t+1}^{\infty} \delta^{s-t} E_t[\pi_{is}^p] \leq \pi_{it} \left(\frac{Q_t}{N} \right) + \sum_{s=t+1}^{\infty} \delta^{s-t} E_t[\pi_{is}^*] \quad (32)$$

Taking the first order condition yields:

$$P(Q_t^*) - c_{it}(q_{it}^*) + N \times P'_t \times q_{it}^* - \frac{\mu_t^*}{1 + \frac{\mu_t^*}{N}} \frac{d\pi^{\text{br}}}{dQ_t} = 0 \quad \forall i \quad (33)$$

In the equation above, μ is the Lagrange multiplier on the incentive

constraint. When the constraint does not bind ($\mu = 0$) the last term equals zero and pricing is as under monopoly. When the constraint binds though, output increases and price decreases in order to ensure that no firm deviates from the collusive equilibrium. The additional term, when comparing with (24), can be conditioned out with a fixed effect, if the researcher has identified a panel of potentially colluding firms, thus making the method empirically applicable.

The optimal behavior in static and dynamic oligopoly, respectively, can be incorporated in one equation, that captures three common oligopolies: Cournot, Bertrand (competitive pricing) and tacit collusion. (Puller, 2006)

$$P(q_{it}^* + q_{-it}) - c_{it}(q_{it}^*) = -\theta_i P'_t q_{it}^* + \frac{\mu_t^*}{1 + \frac{\mu_t^*}{N}} \frac{d\pi^{br}}{dQ_t} \quad (34)$$

In (34), Cournot oligopoly is characterized by $\theta = 0, \mu = 0$, Bertrand by $\theta = 1, \mu = 0$ and efficient tacit collusion by $\theta = N, \mu \geq 0$.

By including an incentive constraint, Puller derives an empirical model that yields a consistent estimation of the conduct parameter, even when firms are engaging in efficient tacit collusion sustained by repeated interaction. Thereby, Puller offers a solution to the critique raised by Corts (1999). Furthermore, as mentioned previously, Genesove & Mullin (1998) show that the indirect estimates of market conduct and cost components predict the "true" values well, using direct cost measures from the American sugar cartel in the end of the 1890s. Using Puller's modification of the model together with the findings by Genesove & Mullin enables us to deal with the critique raised by Corts, and to a certain extent refute it.

To sum up the review of the CPM, the method is widely used by empirical industrial organization economists.¹⁰ There is no doubt that the CPM - as many other methods in this field of work - has its shortcomings, such as the strict functional forms it impose on costs and demand. However, its simplicity, relatively undemanding data requirements and easily interpretable measure of market power continues to support it as a valuable method for IO researchers.

3.3.3 Comparison and Discussion of Methodology

As mentioned in the introduction to section 3.3, a number of suitable methods to answer the research question at hand exist. All those methods share a common aim - to establish the non-infringement or counter-factual scenario that can be used to evaluate the post-cartel price development - but with different approaches. Therefore, only the most relevant were described above. Those methods are useful

¹⁰ A far from complete list of empirical papers using the CPM includes: Orea & Steinbuks (2012), Murakami (2013), Clay & Troesken (2003), Genesove & Mullin (1998), Ellison (1994), and Porter (1983a).

in different cases, depending on data availability, case characteristics, etc. It is therefore important to evaluate which method is most applicable on a case-by-case basis. Further, it can be noted that applying more than one method to each case naturally increases the robustness of the results obtained.

The but-for price estimation is widely used by empirical economists attempting to evaluate the effects of the existence of a cartel. The relevance of the method is underlined by the European Commission's 2011 publication *Quantifying Harm in Actions for Damages*, which aims at "offer[ing] assistance to courts and parties involved in actions for damages by making more widely available information relevant for quantifying harm caused by infringements of the EU antitrust rules" (European Commission, 2011, p. 2). This guidance paper emphasizes the but-for analysis as the single most important tool in quantifying damages. However, it is important to note that such comparator-based methods are not grounded in economic theory.

The main strength of the CPM is its solid foundation in formal economic theory. Moreover, the undemanding data requirements - in the extreme case, consisting of only price and production time series data - combined with an easily interpretable measure of market power and conduct, makes it a desirable method for IO researchers. However it is not without weaknesses. One of the main critique points of the CPM, as mentioned before, is the strict functional forms that it imposes on demand and costs. This might lead to significant biases in the estimated conduct parameter. A potential problem worth noting is that both Genesove & Mullin (1998) and Clay & Troesken (2003) find that the methodology appears to perform reasonably well for low levels of market power. As the method is used here to investigate collusive markets, we expect to estimate large values of market power, at least during the cartel period.

Further, the CPM ignores the potential structural market changes that can have happened between the three identified regimes - such as the entry or exit of an important player in the market or increased foreign competition. It is evident that if the market in question changed significantly, the pre-cartel conduct parameter would not be a good estimator for a post-cartel market in a competitive equilibrium. However, it is the belief of this author, that such significant changes in market structure - to a great extent - can be picked up qualitatively by the researcher.

In the present analysis the CPM is chosen as the preferred method, due to its structural nature and foundation in explicit economic theory, as well as the relatively limited data requirements.

3.3.4 *The CPM in a Post-Cartel Pricing Environment*

The objective of the CPM, as presented above, is to estimate the conduct in a given market, using indirect measures of costs. However, this is only a step on the path to our objective, which is to assess how prices develop in the post-cartel market, compared to an estimated non-collusive equilibrium price level.

We extend the framework of Bresnahan-Lau, by conducting the above analysis on three distinct regimes: pre-cartel, cartel, and post-cartel. This yields the following three expressions, where estimates for pre-cartel, cartel and post-cartel are denoted with an underline, subscript c and overline, respectively.

$$\underline{P} = \underline{\theta}Q^* + \beta_0 + \beta_1Q + \beta_2W + \eta \quad (35)$$

$$P_c = \theta_c Q_c^* + \beta_3 + \beta_4Q + \beta_5W + \epsilon \quad (36)$$

$$\overline{P} = \overline{\theta} \overline{Q}^* + \beta_6 + \beta_7Q + \beta_8W + \phi \quad (37)$$

Here η , ϵ and ϕ are the relevant econometric error terms. Note that Q^* is also dependent on the regime, due to its definition as being dependent on α . If $\overline{\theta}$ is statistically larger than $\underline{\theta}$ over the sample, this serves as an indication that post-cartel prices are larger than what could have been expected but for the cartel, *ceteris paribus*.

In case the two conduct parameters are indeed not equal, the pre-cartel conduct parameter can be used in evaluating the post-cartel prices more specifically. Assuming that the pre-cartel conduct parameter is an expression for a non-collusive equilibrium, we replace the conduct parameter in (37) with $\underline{\theta}$. In the following expression the counter-factual estimate is denoted by squared brackets:

$$[\overline{P}] = \underline{\theta} \overline{Q}^* + \beta_3 + \beta_4Q + \beta_5W \quad (38)$$

This estimation gives us a but-for value for all t in the post-cartel period. In other words, by extending the use of the conduct parameter framework, we end up with a result similar to that of a but-for price estimation. Thus, as is evident, the conduct parameter method can also serve as a useful tool in estimating overcharges during public and private litigation.

A relevant finding to include in our analysis, is Harrington's (2005) theory on optimal cartel pricing in the presence of anti-trust authorities, as discussed in section 2.1. To refresh the mind of the reader, Harrington found that the optimal cartel price, when treating anti-trust penalties as endogenous, is lower than the simple monopoly price when penalties include damages. To put this in perspective of the current discussion, the CPM uses the simple monopoly price, P_M , as a benchmark for 'fully collusive behavior' i.e. $\theta = 1$. If Harrington's argument holds, a θ of one should be defined at this level and not at P_M . An assessment of the impact on the estimate of θ can easily be conducted by constructing a simple graphical example. Denote

the optimal cartel price implied by Harrington's model P_H , the simple monopoly price P_M , the fully competitive price P_0 , and the price observed in the market P_{obs} . Given classic theory on cartel pricing as well as Harrington's (2005) findings, it must hold that $P_0 < P_H < P_M$. Further assume that $P_0 < P_{obs} < P_H < P_M$. Graphically, this translates into what can be seen in figure 5.

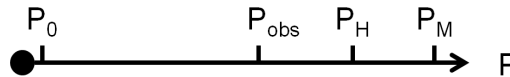


Figure 5: Comparison of collusive prices levels

Assume for the sake of simplicity, that P_{obs} falls in the middle between P_0 and P_M . This would translate into an estimated conduct parameter, θ , of 0.5. If P_H is used as the upper bound, i.e. the fully collusive pricing level, it is evident that $\theta > 0.5$, as P_{obs} falls to the right of the mean between P_0 and P_H . In other words, using a "too high" fully collusive price level translates into a systematically underestimation of the value of θ .

In order to account for this underestimation, the logical next step would be to implement the cartel penalties as an endogenous variable in the collusive firms optimization problem. However, in order to conduct a quantitative analysis - which is our ultimate goal - this would require us to impose structural assumptions on the functional form of $\hat{\phi}(\cdot)$, the probability of detection of the cartel. Such further assumptions will increase the complexity of the model, in a manner that is not deemed reasonable for the purpose of this analysis. Thus, the finding will simply be applied conceptually and qualitatively when interpreting the obtained estimates of θ . Furthermore, if we refrain from attributing too much significance to the absolute levels of θ , but simply compare the relative changes over the different regimes, the misspecification is not expected to affect the interpretation.

3.3.5 Empirical Support for the CPM

This section is devoted to a review of the existing empirical research utilizing the method outlined above. Generally speaking, it is relatively difficult to test the approach empirically, as a number of criteria must be fulfilled: technology must be relatively simple, detailed data on marginal cost and demand must be available, and it must be possible to establish identification of the conduct parameter through non-proportional shifts in demand (Clay & Troesken, 2003).

One of the most significant papers in this regard is Genesove & Mullin (1998), in which the authors compare indirect conduct and cost estimates to direct measures, using data from the American sugar cartel at the turn of the 20th century. Since then a number of studies

have been following a similar approach, including Wolfram (1999), Clay & Troesken (2003), and Murakami (2012), among others.

Genesove & Mullin's widely-quoted 1998 paper uses the conduct parameter method to estimate the departure from marginal cost pricing in the sugar industry during the period 1890-1914. Very generally put, Genesove & Mullin analyze the U.S. East Coast cane sugar refining industry as it is simple in production, underwent dramatic changes in competition, and has widely available data on demand and costs. The homogeneity of the product and the simple production technique, where raw sugar is turned into refined sugar at a fixed and known rate, simplifies their analysis, as a functional form easily can be imposed on the marginal costs. This allows the authors to compare the direct measures of conduct (implied by observable cost information) with indirect estimates (established using econometrics and the conduct parameter method). The authors find that NEIO estimates of industry conduct, as measured by the elasticity-adjusted Lerner index, are reasonably close to the direct measures derived from full cost information, and insensitive to the functional demand form imposed. That being said, this primarily holds for low values of market power, and they do find indications that the method tends to underestimate the conduct parameter, i.e. imply a more competitive behavior than what can be observed in practice.

This is contradictory to the findings of Clay & Troesken (2003) who - when analyzing the US whisky industry at the end of the 19th century - find that conduct parameter is overestimated by the NEIO methodology. As Genesove & Mullin, Clay & Troesken find that the NEIO approach generally performs well for low levels of market power, i.e. low estimates of the conduct parameter, σ . Further, they show that the estimates improve as more direct and observable information on costs are included - similarly to the findings of Genesove & Mullin.

3.4 ANALYSES: HYPOTHESIS TESTING

Now that the analysis design has been laid out and the empirical methodology presented, this section is devoted to the empirical analysis itself. First, *hypothesis 1* will be tested using the German cement cartel as case. Second, suggestions will be given as to how *hypothesis 2* through *5* can be tested if one has access to a more elaborate data set. Finally the results of the empirical analysis are synthesized and summarized.

3.4.1 Case: The German Cement Cartel

In order to carry out an analysis of the price developments, it is necessary to establish a basic understanding of the market for cement and the dynamics that govern it. Further, we need to understand the

background and functioning of the cartel itself. The following two sections are dedicated to exactly this. The review of the cartel is primarily based on Hüscherlath (2013).

3.4.1.1 *The German Market for Cement*

Cement is a powdery substance made with calcined lime and clay, used to set and harden, and to bind other materials together. Although more than 27 different types of cement exist according to the European standard EN 197-1, by far the most common type of cement in Europe is the so-called *CEM I cement*. As such, cement can be regarded as a homogeneous product. The main raw material input is lime and the production process is highly energy intensive. Cement is most commonly used to produce concrete, which in turn is used in the construction industry. Given the seasonality of this industry, production slows down during winter, as a response to a decrease in demand.

Cement markets around the world have a tendency to fall victim of collusive conduct. In several European countries, cement cartels are currently being or have been investigated (Germany, Norway, Sweden, France and Poland to name only a few), and as of March 2014, competition authorities are taking major action against Australian and Brazilian cement producers. Such tendency of cartelization can potentially be explained by the presence of various facilitating factors: a low number of producers, a homogeneous product, high barriers to enter, and an inflexible production process. (Hüscherlath, 2013)

3.4.1.2 *The German Cement Cartel*

On the 4th of July 2002, the German anti-trust authority, the *German Federal Cartel Office (FCO)*, launched an investigation into the existence of a cartel in the cement industry by raiding 30 companies. A number of cement producers were accused of illegally colluding from the early 90s to the end of 2001. The investigation was sparked a by cartel member, Readymix AG, approaching the FCO under the German leniency program. The FCO found that a large number of cement producers divided up the market and elevated prices since the early 90s at least. This eventually lead to the FCO imposing fines of 606 million Euro on the six largest suppliers: Dyckerhoff AG, HeidelbergCement AG, Lafarge Zement GmbH, Readymix AG, Schwenk Zement KG, and Holcim (Deutschland) AG. Previous to the launch of the investigation, in February 2002 Readymix deviated from the collusive agreement by increasing volume deliveries to downstream concrete producers. During the court hearings, the defendants claimed that the price drop following the disclosure of the cartel was the result of a price war, initiated by the deviation by Readymix - and thus that the price level during this period could not be used as an indicator

of a competitive equilibrium. In September 2004, Readymix was acquired by a competitor, Cemex, and the court eventually found that this date was crucial in estimating the competitive price level and thus the but-for price.

Now that we have gained a cursory understanding of the market as well as the cartel, we can proceed with the analysis. First, the data used to carry out the analysis will be described and discussed. Second, the econometric model will be established, and third and finally, the results presented and discussed.

3.4.2 *Data Collection and Sources*

All price and production indices, i.e. cement price, cement production, construction activity, lime stone price, electricity price, and labor cost index, are obtained from the German Federal Statistical Office (DESTATIS). The price index for cement ranges from January 1976 to August 2010, while production index is only available from January 1991. Where relevant, prices and quantities are seasonally adjusted using X12-ARIMA (U.S. Census Bureau, 2013).

The price data is collected by the German Federal Statistical Office directly from the producers, by requesting them to fill out a questionnaire. Here, they are asked to provide price and quantity information on a single representative trade activity, close to the date of the survey. As such, it can be argued that the data can be subject to strategic considerations and thus manipulated by producers (Hüschelrath, 2012). This is a potential bias that should be kept in mind when interpreting the results.

At this point, it should be noted that the fact that production data is only available from 1991 is not optimal. It refrains us from estimating a conduct parameter for the pre-cartel period - as the cartel was initiated in the early 90s - and thus to use this as a benchmark for the post-cartel conduct parameter.

Moreover, it should be noted that in this case, the production of cement is used as a proxy for demand. The construction index is a volume index based on the order backlog in the construction industry, and is comprised of activity in building, housing, and road construction amongst others. A better proxy would be consumption, however such data is not available. The difference between production and consumption is inventorying, i.e. production not consumed (demanded) at the time of production. As cement is a non-perishable good, it must be acknowledged that this difference might be significant. However, for the purpose of this analysis, production is assumed to be an adequate proxy for demand.

The labor cost index is the German labor cost index for manufacturing and service industries, with 2008 as base year.

Finally, all in- and output prices and quantities are monthly, whereas construction activity is quarterly.

The following section will establish the econometric model.

3.4.3 *Econometric Model*

We distinguish between four different regimes: **Pre-cartel period** (Jan 1976 - Dec 1989), **Cartel period** (Jan 1990 - Dec 2001)¹¹, **Punishment phase**¹² (Jan 2002 - May 2005)¹³, and **Post-cartel period** (Jun 2005 - Aug 2010). Figure 6 shows the development of the cement price between 1976 and 2010. Regime changes are shown by the dotted lines.

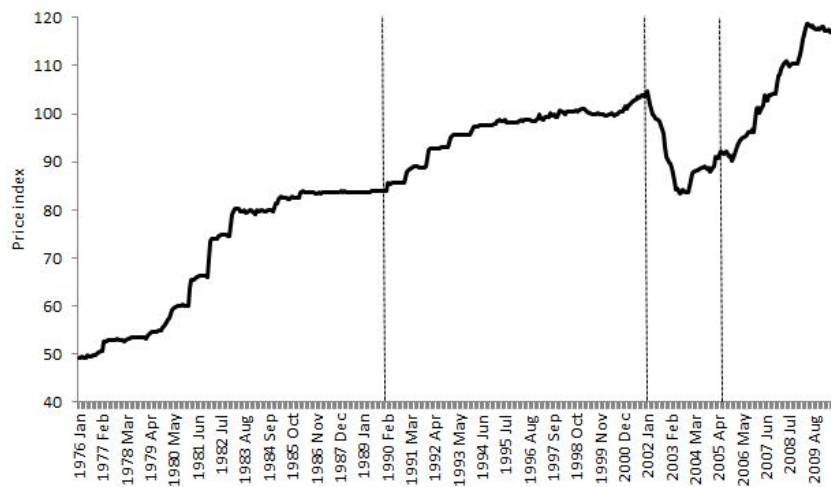


Figure 6: Cement Price Index, 1976-2010, Source: DESTATIS

At first sight, the price developments behave somewhat in accordance with what could have been expected; after a relatively flat development in the end of the pre-cartel period, prices increased steadily following the formation of the cartel. Prices peaked at the height of the cartel in 2001, followed by a decline of 20% over the course of the punishment phase during the following two years. The post-cartel phase, defined to begin in May 2005 was characterized by a steady

¹¹ In the present analysis, Jan '90 is used as the beginning of the cartel, as no more precise information has been found. Most academic papers and newspaper articles refer to the cartel as lasting from the early 90's, as stated in Hüscherlath (2012): "In the course of the investigation, it was found that a large number of German cement producers divided up the German market by a quota system at least since the early 1990s". Following the findings of Frank & Schliffke (2013), the punishment phase is defined as Jan '90 to Dec '01 here.

¹² The cartel was dissolved following a deviation from the agreement by the producer ReadyMix. Therefore, there is a general consensus that the period following the cartel breakdown was characterized by a price-war, where other members of the cartel sought to punish the deviating company.

¹³ During the juridical proceedings, the court estimated a punishment phase lasting from August 2002 to February 2005.

increase in prices - two years into the phase, prices were at level with cartel peak prices. This increase in price in the post-cartel phase can seem curious, but might actually be explained by a number of factors. First, it can be argued that the market is stabilizing following a turbulent time, including a fierce price war during the punishment phase. Second, such a price increase can be driven by fundamentals such as increased demand due to the economic upturn in the mid-2000s. The ambition is that the following analysis will shed light upon the question whether this post-cartel price development is driven by fundamental market developments - or whether it might be a result of residual or tacit collusion. By investigating the conduct parameter, i.e. the degree of competition in the market, we might be able to make inferences about the driving forces behind the observed development.

A good starting point for the econometric analysis is to look at the descriptive statistics of the entire sample (1976-2010) of cement price observations. The descriptive statistics of the original monthly observations across the different regimes can be found in table 1.

	N	MIN.	MAX.	MEAN	STD. DEV.
Pre-cartel	168	49.14	83.99	70.41	13.38717
Cartel	144	83.89	103.82	96.64	5.0081
Punishment	41	83.26	104.64	90.68	5.95608
Post-cartel	63	90.17	118.74	105.94	9.75198
Full period	416	49.14	118.74	86.86	17.25853

Table 1: Descriptive statistics

As can be seen from table 1, the mean price is higher during the cartel period than the pre-cartel period. However, prices during the post-cartel period are even higher than both of the two preceding periods. Another insight from the descriptive statistics is that volatility, as expressed by the standard deviation, is significantly lower during the cartel period than during any other regime. This supports the finding by Abrantes-Metz et al. (2006) and other researchers, which led to the formulation of hypothesis 4, that price variance under collusive behavior is smaller than that of a competitive equilibrium. However, an interesting observation related to *hypothesis 4* is that variance in the post-cartel period is lower than in the pre-cartel period - which could indicate that conduct in the post-cartel behavior is less competitive than in the pre-cartel period. This argument could be further strengthened by testing the differences in the first two moments across the 13 chemical cartels mentioned above, following an approach similar to Bolotova et al. (2008), who employ extensions of ARCH and GARCH models.

Moving on, the first step in the econometric analysis is to estimate the demand function.

3.4.4 Demand function specification and estimation

In general the inverse demand function can be written as follows, as explained in section 3.3.2.1 (Bresnahan, 1982):

$$Q_t = D(P_t, Y_t, \alpha_t, \epsilon_t) \quad (39)$$

where Q_t is the production index of cement, assumed to be equal to demand in equilibrium, P_t the price index of cement, Y_t an exogenous variable, α_t the parameters to be estimated, and ϵ the econometric error term. Following Genesove & Mullin (1998), estimation of equation 39 requires dealing with three issues before proceeding: the frequency of data, the choice of instruments and the functional form of demand.

Monthly data is available for most variables in the current case. When making a choice of the frequency of data, one has to balance two considerations: on the one hand, the benefit of high-frequency data lies in the additional degrees of freedom. However, on the other hand, by doing so one risks measuring the short-term price elasticity, which is expected to be lower than the long-run elasticity. An underestimated short-term elasticity leads to an overestimated monopoly price and thus a underestimated degree of market power. Genesove & Mullin (1998) use quarterly data in their analysis of the sugar cartel, but find that the results are similar when using monthly data. Clay & Troesken's (2003) results - in their analysis of the whisky cartel - are also similar when using monthly and quarterly data. Based on these considerations, and because we wish to include construction activity in our demand function - which is only published every quarter - quarterly data is chosen here. We thus aggregate all data up to quarterly level by taking the arithmetic mean of the monthly observations where applicable.

As price P is clearly endogenous,¹⁴ instrumental variables (IV) are to be introduced, i.e. explanatory variables that are only correlated with price but not (directly) with quantity (Gujarati & Porter, 2009). This is done through a 2-staged least square (2SLS) model. In Genesove & Mullin (1998), *Cuban Imports* are used as IV on the price of sugar. In this case, traditional cost-shifters such as factor prices can prove to be useful instruments. Here, electricity price index and labor cost index are used as instrumental variables. Electricity prices are introduced, as cement production is highly energy-demanding, cf. section 3.4.1.1. The cost of electricity is therefore expected to drive changes in cement

¹⁴ It is commonly known that standard regression methods - such as OLS - are inconsistent and biased when the regressors are correlated with the error term.

price. Labor costs are also believed to influence cement prices, as cement production incurs high transportation costs (which in turn are exposed to changes in labor costs). Finally, electricity prices and labor cost can safely be thought of as exogenous. Alternative instrumental variables such as the price of lignite, another input in cement production, showed no statistically significant importance. In the following both an OLS and a 2SLS model will be applied.

Two functional forms of the demand function will be treated here; linear and logarithmic. Since we are interested in the demand elasticity of cement, η , a logarithmic functional form is useful, because the coefficient to price, P , directly gives an estimate of η . Genesove & Mullin, as well as Clay & Troesken, find no significant difference in using either of four common functional forms (quadratic, linear, log-linear and exponential). The logarithmic base used is e , and this will be the case from here on.

Following the logic of the derivation in section 3.3.2.1, an exogenous demand variable is introduced: the *construction and civil engineering activity*, denoted ConsAct. This variable is expected to capture the pro-cyclicality of cement demand. Further, because the demand for cement is highly seasonal due to a general slow-down in the construction industry during winter months, three quarterly dummy variables are introduced¹⁵.

This leads to the following specification of the demand functions which are to be estimated:

$$\begin{aligned}\log Q &= \alpha_0 + \alpha_1 \log Y + \alpha_2 \log P + \alpha_3 D_{Q1} + \dots + \alpha_5 D_{Q3} + \eta \quad (40) \\ Q &= \alpha_0 + \alpha_1 Y + \alpha_2 P + \alpha_3 D_{Q1} + \dots + \alpha_5 D_{Q3} + \epsilon \quad (41)\end{aligned}$$

where ϵ and η are the econometric error terms and Y is used interchangeable with ConsAct.

As mentioned previously, complete data (price and production) is only available from 1991 and onwards. Therefore, the analysis can only be conducted on (a large part of) the cartel period, the punishment phase and the post-cartel period. However, in order to establish a meaningful demand function, observations during the punishment phase (price war) (2002 Q1 - 2005 Q1) are excluded.¹⁶ This data filtering results in a sample of 66 quarterly observations between 1991 and 2010. As the labor cost index is only available from 1996 and forward, the sample size for the 2SLS is 46 observations. The regression results are shown in the table 2 with heteroscedasticity-consistent standard errors in parenthesis (Hayes & Cai, 2007).

As can be seen from table 2, the elasticity of demand for the logarithmic form is between negative .16-.26%, i.e. highly inelastic. In the

¹⁵ In the regression results in table 2 parameters for quarterly dummies are not shown. These are generally negative in Q1 and usually highly statistically significant for all quarters - which is well aligned with my expectations.

¹⁶ When observations from the punishment phase are included in the demand function estimation, the demand curve is found to be upward sloping.

	(I)LOGOLS	(II)LOG2SLS	(III)LINOLS	(IV)LIN2SLS
N	66	46	66	46
R ² (adj.)	.899	.900	.918	.910
Cons.	3.690*** (1.08)	4.095*** (.889)	89.985*** (16.82)	123.09*** (27.69)
α_1	.480*** (.057)	.338*** (.106)	.466*** (.045)	.452*** (.081)
α_2	-.258 (.201)	-.156** (.076)	-.249* (.133)	-.549** (.207)

Table 2: Demand function estimation. Dependent variables is logQ for (I) and (II) and Q for (III) and (IV). *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. Quarterly dummies for Q1, Q2 and Q3 are included but not shown here. Standard errors are heteroskedasticity-robust following Hayes & Cai (2007). logP and P, respectively, are instrumented using electricity price and labor cost index.

case of a linear demand function, elasticity - evaluated around the mean - is between -.21% (OLS) and -.48% (2SLS). Thus, depending on the functional form and estimation method, elasticity varies between negative .16 and .48%. An inelastic demand is aligned with findings of other studies: Röller & Steen (2002) estimate an elasticity of -.46 for Norway; Jans & Rosenbaum (1996) report an average elasticity of -.81 for regional US markets; Salvo (2004) estimate -.50 across 27 states in Brazil; and Selim & Salem (2010) find that the demand elasticity for cement in France is -.10. An inelastic demand makes economic sense for at least two reasons: cement in general accounts for a low share of construction budgets, and it has few substitutes (Jans & Rosenbaum, 1996).

However, the above demand specification will not enable us to carry out an analysis of the conduct parameter, as the introduction of the level term ConsAct only allows the demand curve to shift. In order to estimate conduct, we need to introduce an interaction term between price and the exogenous demand variable, in order to allow the demand curve to rotate as exogenous demand (through construction activity) varies (cf. section 3.3.2.1). As introducing an interaction term simply as the product of the two explanatory variables potentially leads to multicollinearity, the interaction term is entered using deviations from the mean:

$$(P - \bar{P}) \times (Y - \bar{Y}) \quad (42)$$

where the same logic is used in the logarithmic specification. The introduction of the interaction term leads to the following demand function specifications:

$$\log Q = \alpha_0 + \alpha_1 \log Y + \alpha_2 \log P + \alpha_3 (\log P \times \log Y) + \epsilon \quad (43)$$

$$Q = \alpha_0 + \alpha_1 Y + \alpha_2 P + \alpha_3 (P \times Y) + \eta \quad (44)$$

Note that the interaction term is entering as a deviation from the mean as discussed above, but will simply be shown in the regression as $P \times Y$ (and $\log P \times \log Y$), for the sake of simplicity. Further, the three quarterly dummies are still included in the regression but not shown in the equations above. The results of the regression for the adjusted demand function are shown in table 3

	(I)LOGOLS	(II)LOG2SLS	(III)LINOLS	(IV)LIN2SLS
N	66	46	66	46
R ² (adj.)	.897	.903	.895	.909
Cons.	3.721*** (1.012)	4.342*** (.931)	80.267 (51.929)	132.96*** (37.92)
α_1	.480*** (.057)	.348*** (.100)	.486*** (.070)	.436*** (.095)
α_2	-.264 (.218)	-.202** (.089)	-.162 (.513)	-.640** (.305)
α_3	-.0459 (.693)	.707 (.515)	.005 (.027)	.014 (.023)

Table 3: Demand function estimation with interaction term. Dependent variables is $\log Q$ for (I) and (II) and Q for (III) and (IV). *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. Quarterly dummies for Q_1 , Q_2 and Q_3 are included but not shown here. Standard errors are heteroskedasticity-robust following Hayes & Cai (2007). $\log P$ and P , respectively, are instrumented using electricity price and labor cost index.

As can be seen, the estimates to price and the interaction term are generally not statistically significant in the OLS estimations. Further, in the linear OLS, only the parameter to construction activity is statistically significant (at the 1% level). Therefore we will move forward with the results from the 2SLS regression, where only the interaction term is not statistically significant. The 2SLS estimation yields a demand elasticity between $-.20$ (the parameter to $\log P$) and $-.56$ (evaluated around the mean in the linear formulation), slightly higher than the previous results without the interaction term. That being said, the parameters still point towards an inelastic demand within the same range as previous studies.

3.4.5 Conduct Parameter Estimation

Now that the parameters of the demand-side have been laid out, the next step is to assess the supply relation and finally estimate the conduct parameter itself, following the Bresnahan-Lau framework reviewed in section 3.3.2.1. To recap, the demand side has been estimated by the two 2SLS regressions (leaving out quarterly dummies):

$$\begin{aligned}\log Q &= \alpha_0 + \alpha_1 \log Y + \alpha_2 \log P + \alpha_3 \log(P) \log(Y) + \epsilon \\ \log Q &= 4.34^{***} + .35^{***} \log Y - .20^{**} \log P + .71 \log(P) \log(Y) \\ Q &= \alpha_0 + \alpha_1 Y + \alpha_2 P + \alpha_3 (P \times Y) + \eta \\ Q &= 132.96^{***} + .44^{***} Y - .64 P^{**} + .01 (P \times Y)\end{aligned}$$

Recall equation 30, which is the supply relation following the introduction of an interaction term:

$$P = \theta Q^* + \beta_0 + \beta_1 Q + \beta_2 W + \eta, \quad Q^* = -\frac{Q}{\alpha_2 + \alpha_3 Z}$$

where α_2 is the parameter to price and α_3 the same to the interaction term. Thus, the conduct parameter θ can be estimated by the regression of P on Q^* , Q and W , where the latter is an exogenous variable entering the marginal cost equation. As discussed earlier, the CPM imposes strong assumptions on the functional forms of both the demand and cost function. Thus, in order to proceed with the analysis, some assumptions on the cost function must be made. Recall from section 3.4.1.1 that the main raw material in the production of cement is lime stone. Thus, in the following W is treated as the price index of lime stone.

This regression should be run for each of the periods; pre-cartel, cartel, punishment phase and post-cartel. By doing so, we will obtain a conduct parameter estimate for each of the periods, i.e. an indication of the competitiveness of the industry. Comparing the post-cartel conduct parameter to the pre-cartel estimate would - if possible - *ceteris paribus*, reveal if hypothesis 1 is supported empirically. Here it is assumed that the pre-cartel period is characterized by competitive behavior, and that there are no significant changes in market characteristics (such as the number of players) over the full sample period. If $\theta_{\text{post}} > \theta_{\text{pre}}$, this could be seen as an indication that post-cartel prices are above the competitive level, assuming constant marginal costs and no changes in market characteristics such as number of players - i.e. support for hypothesis 1. On the contrary, if the post-cartel parameter is not statistically different from the pre-cartel parameter, the empirical study would not support the hypothesis. *Alas*, data is not available for the pre-cartel period, thus it is not possible to carry out this comparison. Consequently we will have to rely on a comparison of the conduct parameter during the cartel and post-cartel period, respectively. If no change in θ is observed when switching from one regime to the other, this will support the hypothesis that

prices are above the competitive equilibrium in the post-cartel period and vice versa.

3.4.6 Results and Discussion

In table 4, the relevant regression results of equation 30 for the 2SLS linear specification are presented. Estimates for the logarithmic specification are omitted, as the results are largely similar (the estimated conduct parameters are equally low).

	FULL PERIOD	CARTEL	POST-CARTEL
θ (conduct)	.041*** (.012)	.069** (.031)	.028 (.033)
β_2 (lime)	1.491*** (.123)	.419 (.428)	1.602*** (.205)
N (obs.)	46	24	22

Table 4: Conduct parameter estimates across available pricing regimes (full sample, cartel, post-cartel). Standard errors are in parenthesis. The regression run is 30. *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

Since we do not have direct measures of neither costs nor conduct - as opposed to Genesove & Mullin (1998) - it is difficult to assess the validity of the results. However, this does not deprive us the possibility to interpret and evaluate them given the theoretical framework we are operating within, combined with our knowledge of the cement market and cartel.

The first observation that can be made from the results in table 4 is that all the conduct parameters across pricing regimes are surprisingly low. A conduct parameter over the full period of .041 is similar to the expected outcome of a Cournot market with ~ 24 participants, and very close to full competition ($\theta = 0$). Intuitively, a conduct parameter of .069 during the existence of a hard-core cartel, does not seem valid.

An underestimation of the conduct parameter might stem from a number of sources. First, as deduced in section 3.3.4, the conduct parameter in the post-cartel period might be affected by the fact, that the "correct" competitive level is given by Harrington (2005)'s theory of strategic pricing during litigation. This results, as mentioned previously, in an underestimation of the conduct parameter. Second, even though quarterly data was used, an underestimated short-term elasticity leads to an overestimated monopoly price and thus a underestimated degree of market power. Third, Genesove & Mullin (1998) found that the CPM underestimates the true conduct in the market - which might help explain our results. Finally, errors in the estimate might stem from a misspecification of the model, since the CPM -

as previously pointed out - imposes very strong assumptions on the functional forms of demand and costs.

Even though an interpretation of the absolute levels of the conduct parameters does not yield findings in accordance with the expectations, we turn to a relative comparison of them. It can be seen that the conduct parameter is higher in the cartel period (.069) than over the full period (.041) as well as in the post-cartel period (.028). However, given the point estimate and confidence interval, it cannot be rejected that $\theta_{\text{cartel}} = \theta_{\text{post}}$. In other words, we cannot reject the hypothesis that the post-cartel market is characterized by behavior similar to that of the collusive period, i.e. a non-competitive post-cartel period. In conclusion, given these results, it is impossible to reject or confirm hypothesis 1, based on the current empirical analysis.

Turning to the estimates of β_2 , the parameter to the exogenous cost variable lime stone, W , the significant estimates are between 1.5 and 1.6. This is well aligned with the fact that approximately 1.5 tonnes of limestone is used in the manufacture of 1 tonne cement.¹⁷ In other words, the cost estimates are close to what can be observed in reality.

In conclusion, the empirical analysis of the cement cartel, does not contribute significantly to the general analysis of post-cartel pricing. *Alas*, the analysis did not succeed in neither rejecting nor confirming hypothesis 1. That being said, the results indicate that behavior did shift towards a more competitive nature in the post-cartel period. Further it is important to note, that the methodology is still believed to be applicable if one were to test a larger set of cartels, such as the 13 chemical suggested in section 3.2.1.

The following - and last - section of this chapter is devoted to a brief discussion of how hypothesis 2 through 5 can potentially be tested empirically, if the necessary data were available.

3.4.7 Further Empirical Tests of the Hypotheses

As mentioned previously, the majority of the five hypotheses are expected to be testable given a cross-sectional data set across a number of cartels with differing characteristics - such as the chemical cartels of section 3.2.1. It is evident that these hypothesis can be tested in numerous ways. As such, this section should only be seen as one suggestion on how to perform these empirical analyses.

By applying the above analysis of the German cement cartel on the 13 chemical cartels, I expect that a more valid and reliable result can be obtained regarding **hypothesis 1**, that *given non-efficient markets, the immediate post-cartel prices are expected to be above the competitive level.*

Hypothesis 2, that *post-cartel prices are expected to be higher in markets where the post-cartel period is characterized by a litigation phase, is*

¹⁷ Cement Sector - Industry inputs: <http://www.equitymaster.com/research-it/sector-info/cement/cement-inputs.html>

testable if the cross-sectional data set includes both cartels with and without a litigation phase. By comparing post-cartel conduct parameters across the two types of cartels (with and without litigation phase, respectively), it should be possible to determine if firms price strategically as a result of the litigation phase. This method is less direct than the method applied by Erutku (2012), but is expected to yield similar results, given correct specifications of the models.

With regards to **hypothesis 3**, that *residual collusion can lead to abnormally high post-cartel prices*, the challenge of the researcher is to determine the causality - if any - between residual collusion and abnormally high post-cartel prices. Observed post-cartel prices above the competitive level, determined using e.g. the CPM approach, might stem from a number of sources, including residual collusion. As residual collusion is not directly observable, as in the case of whistle blowing or a litigation phase, an approach similar to that of hypothesis 2 is not applicable. As the task seems insurmountable, I will refrain from giving a concrete recommendation as how to test the hypothesis, and will let this be the topic of future research. Potentially the hypothesis is testable in an experimental set-up.

In the analysis of the German cement cartel, the descriptive statistics revealed that variance of price seemed to follow the predictions by Athey et al. as well as **hypothesis 4**: *as price variance is generally larger during competitive periods than under collusive ones, a non-competitive post-cartel period is expected to exhibit below-average price variation*. Through a statistical analysis, and by comparing variance between pricing regimes, it will be possible to determine if variance in the post-cartel period is below that of pre-cartel periods. This in turn, which will serve as an indicator that the post-cartel period is characterized by non-competitive behavior.

Finally, **hypothesis 5**, that *due to reciprocity, post-cartel periods triggered by whistle blowing or deviation from an agreement, are expected to be characterized by above-average competition*, can be tested using a similar approach as hypothesis 2. First step is to group the cartels of a cross-sectional data set into two: in one group the cartels terminated as a result of whistle blowing or deviation from an agreement and in the other those coming to an end more "peacefully" and based on mutual understanding. By comparing post-cartel conduct parameters across the two groups, it should be possible to reject or accept the hypothesis, *ceteris paribus*.

CONCLUSION

In the preceding sections, we examined how prices are expected to develop in the post-cartel period from both a theoretical and an empirical point of view. By combining the different branches of classic and behavioral economics, industrial organization, finance, and sociology, as well as extending existing models, the theoretical analysis led to the development of five hypotheses on post-cartel pricing.

1. Given non-efficient markets, the immediate post-cartel prices are expected to be above the competitive level
2. Post-cartel prices are expected to be higher in markets where the post-cartel period is characterized by a litigation phase
3. Residual collusion can lead to abnormally high post-cartel prices
4. As price variance is generally larger during competitive periods than under collusive ones, a non-competitive post-cartel period is expected to exhibit below-average price variation
5. Due to reciprocity, post-cartel periods triggered by whistle blowing or deviation from an agreement, are expected to be characterized by above-average competition

These findings indicate that, in practice, we expect post-cartel prices to be above the competitive level, *ceteris paribus* (hypothesis 1). This abnormal price is generally reflected in a lower price variance in the post-cartel period than in a competitive pre-cartel period (hypothesis 4). One explanation to prices being above the competitive level is that explicit collusion is replaced by tacit collusion (hypothesis 3). Moreover, the post-cartel prices are further inflated if the cartel is - or is expecting to be - subject to litigation and/or if the cartel is terminated due to whistle blowing or deviation from an agreement (hypothesis 2 and 5).

As the five hypotheses are derived separately they are not necessarily collectively exhaustive. However, they are believed to provide a good starting point for a relatively unexplored branch of industrial organization. Until this point, no explicit model dealing with post-cartel pricing has been developed, even though Harrington (2004) provides a good foundation for understanding pricing during a litigation phase. Closing this gap in the industrial organization literature is what this thesis aimed at contributing to.

The second part of the thesis, building on the five theoretically derived hypotheses, aimed at empirically testing post-cartel pricing. The

choice of the conduct parameter method - a structural econometric model - was supported and chosen as the most adequate approach to empirical test. Because an elaborate cross-sectional data set across a number of cartels was not publicly available, the empirical analysis of price developments was carried out on a single case: the German cement cartel, taking place from 1990 to 2001. The objective of this case-analysis was specifically to test hypothesis 1, that post-cartel prices are above the competitive level. Using publicly available data from 1991 to 2010, the conduct parameter was derived for the both cartel and post-cartel period. However, the results of the analysis did not enable us to confirm nor reject hypothesis 1.

Even though the results from the empirical analysis of the German cement cartel did not directly contribute towards the objective of the analysis, to test hypothesis 1, it has provided valuable guidance as to how such an empirical test can be carried out.

This academic paper is, to my best belief, the first paper of the sort that utilizes the conduct parameter method to test post-cartel pricing. If replicated on a cross-sectional data set - such as the 13 chemical cartels listed in section 3.2.1, which is unfortunately unavailable to the public - the original approach developed in this paper would allow future researchers to make inferences about pricing behavior in post-collusive markets.

Future research could also focus on many of the aspects covered in this master's thesis, as the entire field of post-collusive pricing is largely unexplored. An original idea, emerging from this work, would be to explicitly treat cartel agreements as incomplete contracts, and evaluate the impact of reciprocity on the enforcement.

APPENDIX

A.1 LETTER OF REJECTION FROM THE EUROPEAN COMMISSION



EUROPEAN COMMISSION
Competition DG

Brussels, 16. 10. 2013
COMP/G6/GM-LoP/mc – D/(2013)102018

Mr. Jacob BERGET

via e-mail
jacob@berget.dk

Subject: GESTDEM 2013/4469 – Application for access to documents according to Regulation 1049/2001 relating to case AT.37857 - Organic Peroxides

Dear Sir,

We refer to your e-mail dated 5 September 2013 in which you make a request for access to a document under Regulation No 1049/2001¹ regarding public access to European Parliament, Council and Commission documents (hereinafter 'Regulation 1049/2001'), registered the same day under the above mentioned reference number. Due to the consultation of the author of the document requested, the period to respond had to be extended by further 15 working days.

1. DOCUMENT CONCERNED

Your application concerns the access to a document belonging to the administrative file AT.37857 – Organic Peroxides. The decision in this case was adopted on 10 December 2003. Several appeals were filed and the matter was definitively adjudicated by the General Court in 2008.

Having carefully examined your request in the light of Regulation 1049/2001, I have come to the conclusion that the document requested falls under the exceptions of Article 4(2), first and third indent of Regulation 1049/2001. Access to this document, therefore, has to be refused. Please find below the assessment as regards the application of the exceptions of Article 4(2), first and third indent of Regulation 1049/2001.

¹ OJ L145, 31.05.2001, page 43.

2. ASSESSMENT UNDER REGULATION 1049/2001 AND APPLICABLE EXCEPTIONS

Pursuant to Article 4(2), first indent of Regulation 1049/2001 the Commission shall refuse access to a document where disclosure would undermine the protection of commercial interests of a natural or legal person.

Pursuant to Article 4(2), third indent of Regulation 1049/2001 the Commission shall refuse access to a document where disclosure would undermine the protection of the purpose of inspections, investigations and audits.

The document you requested access to is the answer by Akzo Nobel to a request for information and is dated 12 May 2002. It contains commercial and market-sensitive information regarding the activities of the involved undertaking, whose public disclosure would undermine the protection of the latter's commercial interests. This information concerns in particular turnover, price levels and yearly price evolutions that constitute an essential part of Akzo Nobel's commercial position. We have consulted the author of the document who confirmed that the disclosure of the document would undermine the protection of the author's commercial interests.

In its judgment *Netherlands v Commission*² the General Court found that Regulation n° 1/2003³ and Regulation n° 773/2004⁴ concerning the rules of anti-trust procedures (which include also cartels) established strict rules on the treatment of the information obtained during the procedures. These Regulations limit the access to the file to the parties concerned by the proceedings and require that the information may only be used for the purposes for which it was collected. The anti-trust procedural rules make it clear that the content of the anti-trust case file which is covered by professional secrecy cannot be disclosed.⁵ In addition, the Court found that the exception concerning the protection of the commercial interests of the undertakings concerned can be applied during a period of 30 years or even more, if necessary⁶.

In the above judgment the General Court also recognized the existence of a general presumption that public disclosure of information collected in anti-trust procedures could undermine the protection of the commercial interests of undertakings concerned as well as the protection of the purpose of the inspections, investigations and audit (Article 4(2), first and third indent of Regulation 1049/2001)⁷. The General Court made it clear that this presumption of non-accessibility should also apply in closed cases.

3. OVERRIDING PUBLIC INTEREST IN DISCLOSURE

Pursuant to Article 4(2) of Regulation 1049/2001, the exception to the right of access must be waived if there is an overriding public interest in disclosing the document

² Judgment of the General Court of 13 September 2013 in Case T-380/08, *Kingdom of the Netherlands v Commission* (Dutch Bitumen).

³ Council Regulation (EC) No 1/2003 of 16 December 2002 on the implementation of the rules on competition laid down in Articles 81 and 82 of the Treaty, OJ L 1, 4.1.2003, p. 1-25.

⁴ Commission Regulation (EC) No 773/2004 of 7 April 2004 relating to the conduct of proceedings by the Commission pursuant to Articles 81 and 82 of the EC Treaty.

⁵ Case T-380/08, *Netherlands v Commission*, paragraph 37-38.

⁶ Case T-380/08, *Netherlands v Commission*, paragraphs 43 and 44.

requested. In order for an overriding public interest in disclosure to exist, this interest, firstly, has to be public (as opposed to private interests of the applicant) and, secondly, overriding, i.e. in this case it must outweigh the interest protected under the exceptions provided in Article 4(2) first and third indent of Regulation 1049/2001.

In your application you have not established arguments that would present an overriding public interest in disclosure. The Commission has also not itself identified such overriding public interest. Consequently, the prevailing interest in this case rather lies in protecting the effectiveness of the Commission's anti-trust investigations and the commercial interests of the undertakings concerned.

4. MEANS OF REDRESS

If you want this position to be reviewed you should write to the Commission's Secretary-General at the address below, confirming your initial request. You have 15 working days in which to do so from receipt of this letter, after which your initial request will be deemed to have been withdrawn.

The Secretary-General will inform you of the result of this review within 15 working days from the registration of your request, either granting you access to the documents or confirming the refusal. In the latter case, you will be informed of how you can take further action.

All correspondence should be sent to the following address:
The Secretary-General
European Commission
B-1049 BRUSSELS

Yours faithfully,



Alexander ITALIANER
Director General

A.2 EUROPEAN COMMISSION COMPETITION CASES 2001-2014

39633 - Shrimps
39861 - Yen interest rate derivatives (YIRD)
39914 - Euro interest rate derivatives (EIRD)
39801 - Polyurethane foam
39952 - Power exchanges
39922 - Bearings
40170 - Exhaust systems
39792 - Steel abrasives
39610 - Power cables
39748 - Automotive wire harnesses
40098 - Blocktrains
40017 - Sugar
39574 - Smart card chips
40032 - BR/ESBR recidivism
39437 - TV and computer monitor tubes
40018 - Car battery recycling
39563 - Retail food packaging
40009 - Maritime Car Carriers
39939 - Optical Disc Drives
39960 - Thermal systems
39972 - Plastic Pipe Fittings
40015 - Plastic Pipe Systems
39966 - Gas insulated switchgear re-adoption
39611 - Water management products
39462 - Freight forwarding
39452 - Mountings for windows and window-doors
39600 - Refrigeration compressors
39605 - CRT glass bulbs
39482 - Exotic fruit (bananas)
39881 - Occupant Safety Systems
39579 - Consumer Detergents
39824 - Trucks
39520 - Cement and related products
39309 - LCD
39258 - Airfreight
39780 - Paper envelope
38866 - Animal Feed Phosphates
38344 - Prestressing steel
39092 - Bathroom fittings - fixtures
36212 - Carbonless paper
38511 - DRAM
39776 - Agricultural film
39459 - Electrical equipment
38589 - Heat stabilisers

39129 - Power transformers
37956 - Concrete reinforcing bar
39396 - Calcium carbide and magnesium based reagents
39401 - E.ON and GdF collusion
39406 - Marine hoses
39125 - Car glass
39188 - Bananas
39181 - Candle waxes
39565 - Grains and oilseeds
39180 - Aluminium Fluoride
38695 - Sodium Chlorate
38624 - Maritime transport of bulk liquids (deep sea)
38543 - International removal services
39419 - International airline passenger services
38628 - Synthetic rubber (NBR)
38629 - Chloroprene rubber
39165 - Flat glass
38432 - Professional videotapes
38710 - Bitumen Spain
39168 - Hard haberdashery: fasteners
37766 - Netherlands beer market
38823 - Elevators and escalators
38899 - Gas insulated switchgear
39234 - Alloy surcharge re-adoption
38638 - Synthetic rubber (BR/ESBR)
39283 - SRAM
38907 - Steel beams
38121 - Fittings
38456 - Bitumen Nederland
38645 - Methacrylates
38620 - Hydrogen peroxide
38443 - Rubber chemicals
38354 - Industrial bags
38281 - Italian raw tobacco
38337 - Thread
37773 - Monochloroacetic Acid
37533 - Choline chloride
38338 - Needles
38238 - Spanish Raw Tobacco
37750 - French beer market
36756 - Sodium gluconate II
38069 - Copper plumbing tubes
38240 - Industrial tubes
37857 - Organic peroxide
38359 - Electrical and mechanical carbon and graphite products
37370 - Sorbates

38279 - French beef
37667 - Speciality graphite
37671 - Food flavour enhancers
37978 - Methylglucamine
37152 - Plasterboard
37784 - Fine art Auction Houses
36700 - Industrial and medical gases
37519 - Methionine
36571 - Austrian banks
37027 - Zinc Phosphate
37919 - Bank charges - Germany
36604 - Citric acid
37614 - Belgian beer market
37800 - Luxembourg brewing industry
37512 - Vitamins
36756 - Sodium gluconate I
36490 - Graphite electrodes
37444 - SAS / Maersk Air

A.3 GERMAN CEMENT CARTEL DATA

The tables below present data on the German cement cartel, used in the empirical analysis of chapter 3.

QUARTER	PRICE	PROD.	CONS.	ELECT.	LABOR	LIME
91-Q1	88.23	88.30	133.5	58.9	—	—
91-Q2	88.93	152.77	137.0	59.2	—	—
91-Q3	88.84	147.03	140.2	59.5	—	—
91-Q4	88.87	124.60	135.3	60.3	—	—
92-Q1	92.69	106.73	148.5	61.6	—	—
92-Q2	92.81	153.13	153.6	61.8	—	—
92-Q3	92.93	153.50	146.7	62.0	—	—
92-Q4	92.99	137.57	142.7	62.1	—	—
93-Q1	95.30	97.47	155.2	63.1	—	—
93-Q2	95.63	156.60	155.7	63.3	—	—
93-Q3	95.63	155.97	153.5	63.4	—	—
93-Q4	95.63	126.90	154.5	63.5	—	—
94-Q1	97.12	106.07	167.5	64.4	—	—
94-Q2	97.48	161.90	171.3	64.8	—	—
94-Q3	97.66	162.40	169.7	64.9	—	—
94-Q4	97.60	152.20	159.3	65.1	—	—
95-Q1	98.09	107.43	167.8	65.4	—	87.8
95-Q2	98.64	153.67	167.9	65.4	—	88.6
95-Q3	98.39	153.57	164.9	65.6	—	87.8
95-Q4	98.18	125.33	150.1	65.9	—	87.6
96-Q1	98.24	76.73	164.1	61.7	73.7	88.3
96-Q2	98.70	154.47	164.4	61.8	84.9	88.3
96-Q3	98.76	156.00	157.9	61.8	76.5	87.7
96-Q4	98.48	128.87	142.9	61.8	90.1	87.3
97-Q1	99.27	84.73	147.8	62.0	76.7	88.6
97-Q2	99.06	152.93	148.2	62.1	86.1	87.9
97-Q3	99.70	149.70	141.7	62.1	77.6	87.0
97-Q4	99.58	126.13	126.6	62.1	90.6	86.4
98-Q1	100.49	95.17	130.1	62.2	76.3	86.2
98-Q2	100.24	148.90	141.8	63.0	88.6	86.3
98-Q3	100.39	153.83	138.5	63.1	79.3	86.1
98-Q4	100.58	118.63	130.4	63.1	91.2	85.9
99-Q1	100.97	93.20	139.7	62.9	77.8	85.6
99-Q2	100.27	154.07	148.2	67.8	90.6	86.1
99-Q3	99.94	163.50	140.5	67.2	81.3	85.9
99-Q4	100.03	135.33	122.2	63.2	92.7	86.3
00-Q1	99.79	97.80	126.7	62.1	79.5	86.8
00-Q2	99.94	151.20	129.6	61.9	93.2	87.0
00-Q3	99.85	149.37	120.9	61.9	84.3	87.4
00-Q4	100.39	123.00	109.3	62.4	96.9	87.4

Table 5: German cement market data, 1991-2000. Source: DESTATIS

QUARTER	PRICE	PROD.	CONS.	ELECT.	LABOR	LIME
01-Q1	101.36	86.40	115.9	64.3	82.3	88.9
01-Q2	102.52	130.67	121.8	64.5	95.7	88.9
01-Q3	103.28	130.70	114.4	64.7	85.9	90.6
01-Q4	103.73	106.80	102.8	64.7	99.0	90.8
02-Q1	103.34	77.43	112.6	67.4	85.5	90.8
02-Q2	99.55	126.40	112.8	67.4	97.3	90.3
02-Q3	98.27	118.67	108.7	67.5	87.8	91.1
02-Q4	93.30	90.40	97.5	67.7	101.0	90.9
03-Q1	89.38	60.63	103.5	70.6	87.5	91.1
03-Q2	84.87	60.63	103.5	70.6	87.5	91.3
03-Q3	83.68	110.63	98.8	70.9	90.1	91.5
03-Q4	83.62	91.80	88.8	71.2	102.1	90.7
04-Q1	87.23	64.77	96.3	73.4	88.4	90.7
04-Q2	88.26	113.77	95.2	73.7	101.6	91.1
04-Q3	88.93	113.53	90.5	73.8	90.3	92.0
04-Q4	88.41	92.17	79.5	73.9	101.3	92.1
05-Q1	89.63	58.73	86.0	76.4	89.7	92.6
05-Q2	91.54	119.20	89.9	76.8	100.8	91.0
05-Q3	91.93	116.73	89.6	77.0	90.6	88.7
05-Q4	90.87	102.03	82.3	77.0	102.1	88.6
06-Q1	92.54	61.17	92.7	79.5	89.1	89.8
06-Q2	94.75	120.60	96.5	79.7	103.2	89.5
06-Q3	95.69	124.13	91.9	80.0	92.3	89.7
06-Q4	96.39	111.03	79.4	80.0	103.6	89.6
07-Q1	100.85	77.70	87.8	84.3	89.6	91.9
07-Q2	102.34	119.23	95.9	84.6	104.2	92.5
07-Q3	103.45	120.33	96.7	85.6	92.9	93.0
07-Q4	104.19	107.03	91.8	86.7	104.8	93.1
08-Q1	108.43	83.97	98.8	90.4	92.5	95.1
08-Q2	110.74	122.63	103.3	90.9	104.6	95.5
08-Q3	110.13	122.70	98.7	91.5	94.5	96.0
08-Q4	110.37	101.90	87.6	92.0	108.4	93.0
09-Q1	113.92	70.73	92.5	95.7	95.4	99.3
09-Q2	118.41	117.80	97.5	97.1	110.3	98.3
09-Q3	118.08	121.27	95.7	97.3	97.1	97.9
09-Q4	117.68	102.23	86.1	97.4	107.3	98.2
10-Q1	117.90	55.83	101.9	99.0	96.2	99.3
10-Q2	117.32	122.97	105.1	99.9	110.6	99.6
10-Q3	117.02	123.30	100.8	100.4	97.7	100.0

Table 6: German cement market data, 2001-2010. Source: DESTATIS. For more specific information on the data and its origin please refer to section 3.4.2.

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