KU LEUVEN

FACULTY OF ECONOMICS AND BUSINESS

Essays on the detection and prosecution of anti-competitive practices



Dissertation presented to obtain the degree of Doctor in Economics

by

Andreas Bovin

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Daar de proefschriften in de reeks van de Faculteit Economie en Bedrijfswetenschappen het persoonlijk werk zijn van hun auteurs, zijn alleen deze laatsten daarvoor verantwoordelijk.

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When it comes to studying collusion or other activities which inhibit competition, two things stand out. First, the job is never finished. Closing the door on one anti-competitive practice merely invites businesses to seek out whatever loopholes or workarounds are available. Posner and Weyl (2018) liken this issue to the *Red Queen* phenomenon, named after the eponymous Red Queen in Lewis Carroll's *through the looking glass*, who tells Alice that "it takes all the running you can do, to keep in the same place".[1] Indeed, regulators find themselves in a constant game of catch-up, discovering whatever workarounds businesses employ and subsequently enacting new laws or regulations. In my personal view, it is more akin to battling the hydra; for each head which is chopped off, two more appear.

Second, for the (empirical) economist, studying this topic is not straightforward for a simple reason: whenever firms are doing something they're not supposed to do, they tend to be secretive about it. As a result, the data required to empirically investigate such practices is often hard to come by. Combined, this might suggest that writing this thesis was a frustrating and thankless effort, and while it was certainly frustrating at times, fortunately, there existed a considerable number of individuals who provided help and/or distraction when needed.

First, I would like to express my gratitude to my supervisor, Patrick Van Cayseele, for giving me the opportunity to undertake this Ph.D, as well as his guidance throughout the years. My sincere thanks to my committee members, who selflessly agreed to assist in this process. Further thanks to my family, who were always supportive. I should also mention my colleagues at KULeuven, especially at LICOS, who managed to make this entire ordeal rather enjoyable. Although I won't go into too much specifics, I would like to single out Julie, with whom I not only shared

[1] In evolutionary biology, the Red Queen hypothesis states that a species is forced to continuously adapt and evolve in order to survive, as it is necessary to keep up with opposing species, who are ever-evolving as well.

an office, but now also share a lot of great memories. A shout out to my friends; I don't know half of you half as well as I should like; and I like less than half of you half as well as you deserve. Lastly, an honourable mention goes to Dries Wouters, without whom I would probably still be figuring out the proofs in the first chapter...

Contents

Doctoral Committee i

Acknowledgements iii

Introduction 3

1 Cartel member or free rider? Detecting cartel participation. 5

1.1 Introduction . . . 6
1.2 Economic evidence . . . 7
1.3 The truck cartel . . . 10
1.4 Theoretical framework . . . 12
1.5 An empirical application: Scania . . . 19
1.6 Conclusion . . . 32

Appendix A Appendix Chapter 1 39

2 Fringe market share as a collusive marker. Evidence from the EEA truck market. 45

2.1 Introduction . . . 46
2.2 Literature review . . . 48
2.3 Empirical evidence . . . 54
2.4 Practical implications . . . 68
2.5 Conclusion . . . 72

Appendix B Appendix Chapter 2 79

3 By object or by effect? The potential harm of first refusal contracts. 89

3.1 Introduction . . . 90
3.2 The right of first refusal . . . 91
3.3 A theory of harm . . . 93
3.4 Bargaining power . . . 104
3.5 Enforcement . . . 107
3.6 Further discussion . . . 108
3.7 Conclusion . . . 110

4 Detecting excessive pricing within a bargaining framework 117
4.1 Introduction . . . 118
4.2 The market . . . 120
4.3 The case . . . 125
4.4 Theoretical framework . . . 132
4.5 Empirical analysis . . . 135
4.6 Conclusion . . . 144

Appendix C Appendix Chapter 4 151

General Introduction

In the detection and - particularly - prosecution of anti-competitive practices, economic evidence is often relegated to a secondary role. Conventional wisdom suggests that whatever suspicious behaviour an economic practitioner may identify is insufficient to establish collusion, unless all alternative explanations for such conduct can be ruled out. For example, as firms react to a shared business environment, a simultaneous reduction in output or increase in price is considered to be a feature of both competition and collusion. In turn, this has led legal scholars to raise the standard of proof, suggesting that negative evidence, i.e. evidence which shows that something did not occur, might be exactly what is needed in these types of cases (Kovacic et al., 2011).

In keeping with this logic, this dissertation provides a number of contributions aimed at identifying anti-competitive practices, based on demonstrating that a firm's behaviour is contrary to what would be expected under competition. The infringements discussed can be largely subdivided into two categories, which overlap with the prohibitions contained in Articles 101 and 102 of the Treaty on the Functioning of the European Union (TFEU). Chapters 1 and 2 focus on infringements of Article 101, which prohibits agreements that have as their object or effect the restriction of competition. Chapters 3 and 4 are closely linked to infringements of Article 102, which prohibits firms from abusing a position of dominance.

The first two chapters present methods which allow for the detection of collusive conduct at the firm-level. The discussed methodologies can be - to a certain degree - considered complementary. Chapter 2 examines market share dynamics on the EEA truck market, which was characterized by the presence of a cartel between 1997 and 2011. Economic theory suggests that in the presence of a cartel, outsiders are able (and willing) to undercut the collusive price, thereby expanding their share of the market.

An empirical investigation suggested that this was indeed the case, as non cartel firms were able to maintain a larger joint market share during the cartel years. Based on this insight, the chapter presents evidence of cartel participation on behalf of a firm which denied acting in a non-competitive manner: Scania. Scania's market share decreased during the cartel period, followed by an increase after its dissolution. As this pattern of behaviour is inconsistent with that of an outsider, it in turn suggests cartel participation.

That being said, it cannot be excluded that individual cartel participants experience an increase in market share. While economic theory suggests that the joint market share of colluding firms is likely to decrease, this need not be the case at the level of the individual conspirator. Consequently, chapter 1 presents a more refined approach to establish cartel participation based on the notion that firms are both profit maximizers and cost minimizers. Both optimization problems yield expressions for unobserved marginal costs, which are presumed to match if the underlying assumptions are satisfied. If not, a divergence between both could suggest that a firm is no longer maximizing its own profits (a hallmark of competitive behaviour), but rather the joint profits of itself and any number of co-conspirators, suggesting collusion. While a more refined approach, the methodology presented in this chapter is somewhat more data-intensive compared to chapter 2, meaning both have their merits, and could co-exist as tools in the economist's toolbox.

Chapter 3 provides a more theoretical interlude, as it investigates first refusal contracts. In presenting a theory of harm, the chapter discusses a number of undesirable outcomes which might result from these agreements, which are not prohibited under competition law. More specifically, it is demonstrated that in a horizontal setting, this type of contract might result in outcomes similar to those resulting from joint profit maximization between two firms. Moreover, as these contracts often occur in situations characterized by bargaining asymmetries, it is argued that they could constitute an abuse of bargaining power.

In making these considerations, chapter 3 is closely related to chapter 4. This final chapter examines bilateral contracting in the zinc industry, in order to investigate whether excessive pricing occurred. To do so, a bargaining framework is employed based on the notion that in supply chains, there often exists an upper bound on the price charged by upstream firms to their downstream counterparts. Firms on neither side of the supply chain wish to see too many of their counterparts leave the market, as this could hurt their future margins.

In turn, this upper bound is related to the *no economic sense* criterion, which

states that conduct should be prohibited if it makes "no economic sense but for the tendency to eliminate or lessen competition" (Werden, 2005). If contracts implement outcomes which go beyond what a party with absolute bargaining power would obtain, it is argued that this party must be pursuing a goal that goes beyond what can be rationalized economically. In estimating this upper bound, it is found that one firm charged prices which far exceeded this benchmark, suggesting the presence of excessive pricing.

1

Cartel member or free rider? Detecting cartel participation.

1.1 Introduction

In the prosecution of cartels, competition authorities prefer the use of direct evidence, sometimes referred to as a 'smoking gun'. Generally speaking, direct evidence consists of written or oral statements which both explicitly describe the collusive agreements and identify the participants. Nonetheless, it has been recognized that economic evidence can play a significant role in cartel cases, either due to the absence of a smoking gun or to support direct evidence in a cumulative manner.

Both from a legal and economic perspective, there has been much debate on the effectiveness of economic evidence, see for instance Werden (2003). Although unusual bidding patterns, simultaneous price hikes and other forms of parallel conduct are features of collusion, they are often considered insufficient to exclude competition. Fundamentally, economic evidence needs to demonstrate that any suspicious actions taken by the defendants were the result of prohibited agreements.

In light of this issue, this chapter proposes a novel approach to detect collusive conduct, which discerns between competitive and concerted behavior at the firm-level. The approach taken consists of comparing implied marginal costs under the assumption that (i) firms maximize their own profits and (ii) minimize costs. If both assumptions are satisfied, cost estimates are presumed equal. However, if firms cooperate and assumption (i) is violated, estimates will diverge. Based on this intuition, a switching regression framework in the style of Porter (1983) and Lee and Porter (1984) is employed to detect changes in competitive conduct.

As an empirical application, I examine the conduct of Swedish truck manufacturer Scania, which was accused of participating in a price-fixing cartel on the EEA market from 1997-2011. Scania denied all allegations, arguing that the documentary evidence provided by the European Commission (EC) was insufficient to prove collusive conduct. Despite of this, the EC concluded that Scania had broken antitrust rules.[1] The results of this chapter agree with the EC's decision, as it is found that Scania acted in a manner which was not consistent with the behavior of a strategic outsider during the cartel period.

The rest of this chapter is structured as follows: Section 1.2 reviews the literature on the detection of collusive conduct and the role of economic evidence in the prosecution of cartels, followed by a discussion of the trucking cartel in section 1.3. Section 1.4 discusses the methodological framework, which in section 1.5 is applied

[1] In 2017, the European Commission ruled that Scania had broken EU antitrust rules, a decision which was later appealed by Scania. The appeal was dismissed by the General Court in 2022.

to Scania as a proof of concept. Section 1.6 concludes.

1.2 Economic evidence

Cartel prosecution There has been much debate on the role of economic evidence in cartel cases, see for instance Baker (1993) or Werden (2003). This debate has mainly centered around the often ambiguous nature of this type of evidence. Economists have since long recognized that independent decision making can lead to outcomes which are similar to those that arise under unlawful agreements. In an oligopolistic setting, interaction between firms could result in parallel behaviour as firms react to a shared business environment.

As a consequence, parallel conduct is considered insufficient to establish collusion. Still, it is generally acknowledged that economic evidence can serve a purpose in the prosecution of cartels. Case law shows that parallel conduct itself is often used in a cumulative manner, supplementing direct evidence.[2] Moreover, in cases where the plaintiff needs to rely on circumstantial evidence to establish collusion, economic evidence is more likely to play a key role.

As parallel conduct on its own does not exclude competition, this has led courts to raise the standard of proof: economic evidence needs to distinguish between actions which are the result of unlawful agreements, and actions resulting from independent decision making (Kovacic et al., 2011). In US antitrust law, a concept which can be considered key in making this distinction is the *action against self-interest*. If firms take actions which can be considered contrary in a competitive scenario, but are economically rational in a collusive context, this could allow for the exclusion of independent action. In the present chapter, I propose a methodology which applies this criterion in order to discern between competition and collusion.

As a motivating problem, I examine the case of truck manufacturer Scania, which was accused of participating in a price-fixing cartel on the EEA market. With the exception of Scania, which denied any wrongdoing, all of the accused firms agreed to a settlement, admitting to the charges in unequivocal terms. Scania motivated its refusal to settle by claiming that the EC's evidence - which showed that Scania representatives took part in regular information exchanges - was insufficient to prove collusive conduct:

[2]For a more elaborate discussion and examples, see the OECD roundtable on prosecuting cartels without direct evidence.

> "Scania contests that any explicit agreements between the participants were underlying their discussions. Scania also contests that it ever was a party to any agreements to increase prices, to coordinate its pricing behaviour or to collude with competitors on any competitively relevant parameter. Scania argues that the Commission must prove beyond reasonable doubt that Scania has participated in an infringement [...]"[3]

The EC ruled that the documentary evidence was sufficient, concluding that Scania had engaged in prohibited agreements resulting in a distortion of competition.[4] The Scania case highlights both the potential of economic evidence and its problematic nature. On the one hand, methods which allow for the detection of infringements might discourage colluding firms from making similar arguments, provide additional proof in the absence of sufficient documentary evidence, or prevent wrongful convictions.

On the other hand, it is acknowledged that in the presence of a cartel, outsiders have an incentive to free ride, e.g. d'Aspremont et al. (1983) or Deneckere and Davidson (1985). If a cartel starts to increase the price of its products and prices are strategic complements, outsiders are expected to increase their prices as well, resulting in parallel conduct regardless of cartel participation. Economic evidence should therefore be able to distinguish between the actions of a cartel member and those of an outsider.

Detecting collusion There exists a large body of literature dedicated to the detection of collusion. For a good overview, see Harringon (2008). However, for the current purpose, some commonly used approaches seem less suited. While methods which search for abrupt changes in firm behavior (e.g. Crede, 2019 or Boswijk et al., 2019) are useful as the starting point of a deeper investigation, they are unlikely to distinguish between cartel participation and free riding.

In order to disentangle market forces from collusion, I propose an approach which attempts to detect changes in a firm's conduct given that it behaves as an optimizing agent. In competition, firms are assumed to maximize their own profits, whereas under collusion they internalize (to a certain degree) the effect of their

[3] CASE AT.39824 -Trucks; Commission Decision of 27.9.2017, pp. 61.

[4] To counter Scania's line of argumentation, the EC relied on case law stating that even if a firm does not abide by the anti-competitive outcome of such meetings, this does not relieve them from the responsibility of participation unless they are on the record publicly distancing themselves, see CASE AT.39824 -Trucks; Commission Decision of 27.9.2017, pp. 57.

actions on their competitors' profits. At the same time, optimizing firms will attempt to minimize costs of production, regardless of wether or not they are cooperating.

Both optimization problems yield analytical expressions for unobserved costs, which under correct conduct assumptions are assumed to match. If a divergence between both estimates suggests that a firm is no longer maximizing its own profit, this could be considered inconsistent with competition. From a legal perspective, this would qualify as economic evidence which satsifies the required standard of proof. As Werden (2003) notes, rebutting the hypothesis of individual maximizing behavior constitutes evidence of actions contrary to self-interest.

This approach is closely related to the literature on conduct parameters, notable examples of which include Genesove and Mullin (1998), Ciliberto and Williams (2014) and Miller and Weinberg (2017). Similarly, these methods attempt to capture deviations from a structural model of oligopoly using so-called conduct parameters. Under the assumption that competitive firms maximize their own profits, these parameters measure the weight firms place on the profits of their competitors. A positive estimate therefore provides evidence against the null hypothesis that conduct is competitive. There are, however, some important differences.

First, conduct parameter estimation is a data intensive process, which generally relies on detailed data at the industry-level. As I attempt to detect collusion at the firm-level, the data employed mainly consists of observables on that individual firm. The proposed approach can therefore be considered a middle ground between more parsimonious methodologies which are unable to satisfy the required standard of proof, and more data intensive methods.

Second, conduct parameter methods contrast the marginal cost expression obtained under profit maximization with an estimated cost function.[5] Reiss and Wolak (2007) point out that identification of the conduct parameter hinges on the functional form assumptions on marginal cost. In other words, any recorded deviation from competition might also be due to misspecification of the cost function. I attempt to avoid this problem by embedding the functional form for marginal cost within the structural model of firm behavior.

Perhaps most closely related to the proposed method is the work done by De Loecker and Scott (2016) and Nevo (2001). The former use implied marginal costs under profit maximization and cost minimization to measure markups in the US

[5]For example, Ashenfelter et al. (2015) and Miller and Weinberg (2017) assume that shipping distance between markets and breweries is an important determinant of costs in the brewing industry, specifying a marginal cost function in terms of these distances.

beer industry. They concluded that the estimates were similar and plausible, which in turn corroborated the underlying assumptions, including those on competitive conduct. Nevo (2001) estimates marginal costs and the corresponding markups in the ready-to-eat cereal industry under different conduct assumptions (e.g. own- versus joint-profit maximization), which he compares with accounting measures of the markup in order to assess which model of conduct fits the industry.

1.3 The truck cartel

On September 20th, 2010, German truck manufacturer MAN blew the whistle on the cartel and entered into a leniency deal with the EC. The subsequent investigation ended a price-fixing conspiracy that had lasted for fourteen years (1997-2011), covered the entire EEA market and resulted in record fines totaling €2.92 billion. The accused firms were the six largest truck manufacturers on the European market: Daimler, MAN, Volvo/Renault, Iveco, DAF and Scania.

During the cartel period, these firms colluded on the price of medium (6-16 tons) and heavy trucks (over 16 tons). In addition to this, they delayed the introduction of new emission technologies, the costs of which were passed on to the costumer. Jointly, the cartel served over 90% of the EEA truck market in both heavy and medium trucks. As Scania exclusively produces heavy trucks, attention will be restricted to this segment throughout the rest of the chapter.[6]

In the truck market, price setting starts from a gross price list, which is issued by the headquarters of each respective company and contains information on the price of base models and available options, allowing for custom assembly. These paper lists were later on replaced with computer based 'truck configurators'. Trucks are imported locally via distributors, e.g. Scania Germany, who pay transfer prices equal to the gross list price minus discounts.

At the local level, distributors then decide on the price charged to dealerships in a similar manner using a distributor gross price list, to which discounts are applied, resulting in a dealer net price. The final consumer price is determined by the dealerships and consists of the dealer net price and his margin. Both dealerships and distributors can be wholly-owned or third party companies.

During the cartel, the manufacturers increased and harmonized prices at the factory gate level across the EEA. This was facilitated by the introduction of the Euro

[6] see CASE AT.39824 -Trucks.

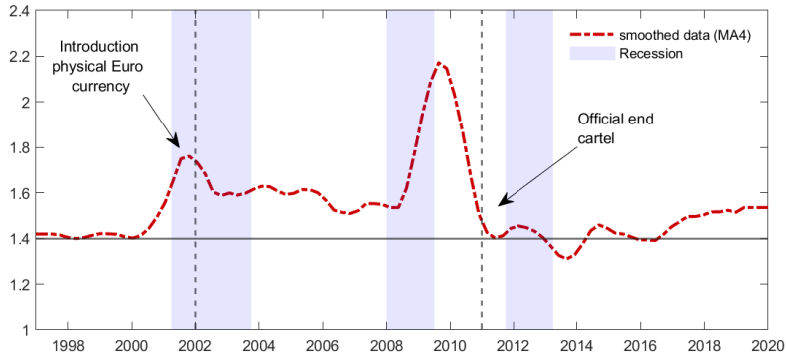


Figure 1.1: Scania's deflated revenue/truck sold on the European market (SEK mil.).
Source: Own calculations based on Scania's quarterly reports.

currency, which resulted in EEA-wide gross price lists for all of firms except Iveco. After the introduction of the Euro, the cartel members started to systematically exchange information and reduce discounts given on the gross list price.[7] The resulting loss in consumer welfare depends on how overcharges are passed on through the supply chain. The EC did not provide a damage estimate, although Beyer et al. (2020) find an upper bound on the overcharge on individual net prices equal to 7.6%, which amounts to €43.4 billion in total.

Starting in 1997, pricing information was regularly shared via organized meetings, emails and telephone calls. Discussions first took place at the headquarters level, but after 2004 were continued at the German subsidiary level. Documentary evidence shows that the cartel members shared price lists, configurators and coordinated on gross price increases. As an example, an excerpt from an email sent by a Scania employee in 2005 on "competitors exchange material" is included:

> "At our meeting last week we gave all of you the current [...] price list (based on German market). Please send us yours too if possible, if not give us a short info concerning the way we want to exchange it in the future (e.g. contact direct German market responsible persons) and if it is possible to give us a configurator or just pdf files."[8]

Despite of this, Scania maintained its innocence, arguing that any exchange of

[7] CASE AT.39824 -Trucks; Commission Decision of 19.7.2016, pp. 13.
[8] CASE AT.39824 -Trucks; Commission Decision of 27.9.2017, pp. 39.

information, which they claimed was of limited value and unreliable, did not result in anti-competitive behavior. Looking at figure 1.1, Scania's quarterly revenue per truck sold on the European market (which is deflated using the EU28 PPI and smoothed using a quarterly rolling average) starts to increase around 2001, which is in accordance with the EC's timeline as the truck manufaturers used the Euro introduction to increase their prices. Afterwards, it was at a consistently higher level untill 2011. Post-2011, there is a return to the pre-2001 level.

One interesting feature of the price path is that it is interrupted by two temporary spikes, the smaller one coinciding with the early 2000s recession and the larger one with the 2009 recession. A possible explanation could be that negative demand shocks decrease the profits from cheating, thereby allowing a cartel to set higher incentive compatible prices during a period of economic downturn, resulting in countercyclical pricing as discussed by Rotemberg and Saloner (1986). Alternatively, it could be argued that this price spike might be due to measurement error. Yet this does not seem to be the case as a similar albeit less pronounced price spike is present in Scania's global average truck price.

As previously mentioned, figure 1.1 is not necessarily indicative of anti-competitive behavior. If trucks are substitutes and the other truck manufacturers increased their price, Scania's price is expected to follow regardless of cartel participation. As some of the cartel's demand is expected to be diverted to Scania's product portfolio, this would allow it to set higher prices without decreasing overal profits. The next section therefore presents a simple framework which tries to determine if this price increase was the result of collusive conduct.

1.4 Theoretical framework

1.4.1 Profit maximization

Suppose a market consists of multi-product firms producing a total of J differentiated goods. Each firm sets prices in order to maximize an objective function Q. Consider a firm f with a product subset $\mathcal{F}_f = \{q_m, q_{m+1}, ..., q_{m+n}\}$. Its optimization problem

can be stated as

$$\begin{aligned}\max_{p_m,\ldots,p_{m+n}} Q_f &= \pi_f(\mathbf{p}) + \phi \sum_{g\neq f\in\mathcal{G}} \pi_g(\mathbf{p}) \\ &= \sum_{j=m}^{m+n} q_j(\mathbf{p})p_j - C_j(q_j) + \phi \sum_{g\neq f\in\mathcal{G}} \sum_{j\in\mathcal{F}_g} q_j(\mathbf{p})p_j - C_j(q_j).\end{aligned} \tag{1.1}$$

In competition, f maximizes its own profit π_f, with p_j, q_j and C_j denoting the price, unit sales and total (variable) production costs of product j. Sales are a function of the price of all goods in the market, denoted by a $J \times 1$ vector $\mathbf{p}$.

Following the literature on conduct parameter estimation, (1.1) allows for flexible competition by introducing a parameter $\phi \in [0, 1]$. This parameter dictates the weight f places on the profits of its co-conspirators, with the subset of colluding firms denoted as $\mathcal{G}$. The objective function nests both competitive behavior ($\phi = 0$) and joint-profit maximization ($\phi = 1$).[9]

Let $f \notin \mathcal{G}$, meaning $Q_f = \pi_f$. In an interior Nash equilibrium, the price of each product k produced by f satisfies the following first-order condition

$$0 = \sum_{j=m}^{m+n} \frac{\partial q_j}{\partial p_k}\left(p_j - \underbrace{\frac{\partial C_j}{\partial q_j}}_{c_j}\right) + q_k, \tag{1.2}$$

yielding the standard condition that marginal cost c_j equals marginal revenue in the optimum. Re-arranging and stacking the first-order conditions for each product $k \in \mathcal{F}_f$ yields the following system of $n + 1$ equations

$$\underbrace{\begin{bmatrix} q_m \\ \vdots \\ q_{m+n} \end{bmatrix}}_{\mathbf{q_f}} = \underbrace{\begin{bmatrix} \frac{\partial q_m}{\partial p_m} & \cdots & \frac{\partial q_{m+n}}{\partial p_m} \\ \vdots & & \vdots \\ \frac{\partial q_m}{\partial p_{m+n}} & \cdots & \frac{\partial q_{m+n}}{\partial p_{m+n}} \end{bmatrix}}_{\mathbf{A}} \underbrace{\begin{bmatrix} c_m - p_m \\ \vdots \\ c_{m+n} - p_{m+n} \end{bmatrix}}_{\mathbf{c_f - p_f}}. \tag{1.3}$$

Assuming the total market consists of gross substitutes and an outside option, $\mathbf{A}$ is a strictly diagonally dominant matrix with a negative diagonal and positive off-diagonal (for further discussion, see appendix A.1). As a result $\mathbf{A}$ is non-singular

[9] The objective function can easily be modified to allow for weights to vary across competitors (Miller and Weinberg, 2017), markets (Ciliberto and Williams, 2014), etc... However, without loss of generality, we proceed using the baseline specification from (1.1).

and (1.3) can be re-written as

$$\mathbf{c_f} = \mathbf{A}^{-1}\mathbf{q_f} + \mathbf{p_f}, \tag{1.4}$$

meaning

$$c_k = \sum_{j=m}^{m+n} a_{jk}^{-1} q_j + p_k \tag{1.5}$$

for each $k \in \mathcal{F}_f$.

Suppose some subset $\mathcal{G}$ of firms agrees to cooperate. As long as $f \notin \mathcal{G}$, equation (1.5) still holds for each $k \in \mathcal{F}_f$. This equation therefore yields an analytical expression for marginal cost if (i) all firms behave in a competitive manner or (ii) some subset of firms start to collude, but f is not part of the cartel, meaning its objective function stays unchanged. However, should f place a weight on the profits of other firms in its objective function and actively participate in a cartel, it is easily seen that this is no longer the case.

1.4.2 Cost-minimization

An optimizing firm f will attempt to minimize the costs incurred to produce a desired amount of output. It therefore solves the following constrained optimization problem for each product $k \in \mathcal{F}_f$

$$\min_{\mathbf{v}_k} C_k \equiv \mathbf{v}_k(\mathbf{p}^v)' \quad \text{s.t.} \quad q_k(\mathbf{v}_k) \geq \bar{q}_k, \tag{1.6}$$

with q_k and $\bar{q}_k$ denoting the actual and target output, which is produced using a vector $\mathbf{v}_k$ of inputs. The corresponding vector of input prices is denoted as $\mathbf{p}^v$ and $q_k(\mathbf{v}_k)$ is a production function, which maps a bundle of inputs into an output space. In an interior optimum, the following first-order conditions hold for each k

$$\mathbf{p}^v = \lambda_k \nabla q_k(\mathbf{v}_k), \tag{1.7}$$

as cost-minimizing firms equalize the marginal product per dollar spent across its inputs. The Lagrange multiplier λ_k yields the marginal change in the objective function when relaxing the constraint, meaning it equals the marginal cost of k in

the optimum. For any variable input $i \in \mathbf{v}_k$, it follows from (1.7) that

$$c_k \equiv \lambda_k = \left(\frac{\partial q_k}{\partial v_{ik}} \right)^{-1} p_i, \tag{1.8}$$

which following De Loecker and Warzynski (2012) can be further re-written to obtain

$$c_k = \left(\underbrace{\frac{\partial q_k}{\partial v_{ik}} \frac{v_{ik}}{q_k}}_{\theta_k^i} \right)^{-1} \underbrace{\frac{p_i v_{ik}}{q_k}}_{S_{ik}}. \tag{1.9}$$

The marginal cost of product k is equal to the ratio of expenditure on any variable input i to the total quantity of k sold, denoted as S_{ik}, divided by the output elasticity of that input, denoted θ_k^i.

1.4.3 A collusive marker

Equation (1.9) holds for any variable input and - importantly - requires no assumption on competitive conduct. Following De Loecker and Scott (2016), this conduct-free expression can therefore be contrasted with the closed-form expression from equation (1.5) in order to assess competitive conduct. Suppose all assumptions are satisfied, such that

$$S_{ik} \left(\theta_k^i \right)^{-1} = \sum_{j=m}^{m+n} a_{jk}^{-1} q_j + p_k. \tag{1.10}$$

In appendix A.2, it is formally shown that if k is produced by a colluding firm, (1.10) no longer holds with equality, and

$$S_{ik} \left(\theta_k^i \right)^{-1} - \sum_{j=m}^{m+n} a_{jk}^{-1} q_j \begin{cases} = p_k & \text{if } f \notin \mathcal{G}, \\ < p_k & \text{if } f \in \mathcal{G}. \end{cases} \tag{1.11}$$

A divergence over time between both sides of (1.10) could therefore signal a change in f's objective function, which in turn implies a switch in competitive conduct. If f is no longer behaving as an independent own-profit maximizer, this would constitute an action against self-interest (as per the legal definition), thereby providing evidence against competitive conduct.

In this chapter, I employ the firm-level analog to equation (1.10), which is obtained by taking the share-weighted sum of marginal costs, i.e. the average

marginal cost, using both marginal cost expressions, such that

$$c_f = \sum_{k \in \mathcal{F}_f} \sigma_k c_k, \quad \text{with} \quad \sigma_k = \frac{q_k}{\sum_{j \in \mathcal{F}_f} q_j}, \tag{1.12}$$

which yields

$$p_f = \left(\theta_f^i\right)^{-1} S_{if} - \sum_{k \in \mathcal{F}_f} \sigma_k \sum_{j=m}^{m+n} a_{jk}^{-1} q_j. \tag{1.13}$$

In this case, p_f denotes the average price over all products sold by f, whereas θ_f^i is a local measure of the overall or aggregate output elasticity of input i. Lastly, S_{if} denotes the ratio of total input expenditure on a variable input i to total unit sales (for the derivation, see appendix A.3). From a practical perspective, this equation is far more useful in the case of multi-product firms, as input expenditure is generally not reported in a product-by-product manner.

In the next section, I attempt to classify Scania's competitive conduct over time based on this framework. However, comparing both sides of (1.13) is not straightforward as it is formulated in terms of unobservables, i.e. the output elasticity of a variable input and the derivative of demand with respect to price. Moreover, it is not possible to specify a parametric form for these unobservables and use (1.13) as an estimation equation, as competitive conduct - being the main variable of interest - is presumed to be unknown. In order to circumvent this problem, I estimate both conduct and the model parameters simultaneously using a switching regression model as employed by Porter (1983) and Lee and Porter (1984).

1.4.4 Preliminaries

Relevant market Profit-maximization assumes the existence of an equilibrium in a specific market and therefore requires a clear notion of what constitutes the relevant market, both geographically and in the product dimension. In the case of trucks, the geographic issue has been discussed in the context of various merger cases, with the EC concluding it was not clear if the relevant market was the community market or the different national markets.[10]

[10] See for instance, the Volvo/Renault merger in 1990, in which EC had concluded it was not clear if the relevant market for heavy trucks was the community market or rather the different national markets (See Case No COMP/M.1980 - VOLVO / RENAULT V.I.). This was also the case in the discussions on the MAN/Scania (2004) and the Volkswagen/MAN (2010) mergers, although there were indications favoring defining the market as EEA-wide (See Case No COMP/M.4336 - MAN / SCANIA and Case No COMP/M.6267 - VOLKSWAGEN / MAN).

I start from the existence of an equilibrium at the EEA level. The colluding truck manufacturers admitted to increasing and aligning gross list prices across the EEA using pan-European gross price lists, and over time shared their price setting algorithms. As a result, it is assumed they shared their European pricing strategy in an attempt to maximize joint-profits across the EEA.

Regarding the relevant product market, the EC stated in the context of the MAN/Scania merger that - based on consumer testimonies - trucks fall into three categories with no further segmentation: light, medium and heavy trucks; "[T]he Commission [...] concludes that trucks belong to different relevant product markets depending on their gross weight."[11]

Firm ownership In an oligopolistic setting, ownership plays an important role in firm behavior. For instance, merged firms are assumed to maximize joint-profits as they become a single enterprise. As our approach explicitly relies on firms maximizing an objective function, it is of key importance that elements which influence this function are included. Both Volvo and MAN possessed a sizable stake in Scania at certain points in time. Firms acquiring a non-controlling stake in their direct competitors, also referred to as cross-ownership, has long been considered to potentially soften competition and facilitate tacit collusion (Gilo et al., 2006).

More importantly, Scania is a wholly owned subsidiary of Volkswagen since 2014. Although Volkswagen is not active on the EEA truck market itself, it acquired sole control of MAN in 2011, at which time it also possessed a majority of the voting shares in Scania (70.94%). As of 2020, both MAN and Scania are subsidiaries of the Volkswagen owned Traton Group. Although a formal merger has not been concluded, MAN and Scania have developed significant interlinkages since 2011 as part of Volkswagen's strategy to form a strong challenger to its chief competitor Daimler.

A framework by Backus et al. (2021) is therefore employed, which allows for ownership to be included in a firm's objective function. If the cash-flow rights of an investor s in a firm f are denoted as β_{fs}, the profits accruing to the investor can be written as

$$\pi_s = \sum_f \beta_{fs} \pi_f. \tag{1.14}$$

If a firm attempts to maximize the profits of its shareholders, its objective function

[11] See Case No COMP/M.6267 - VOLKSWAGEN / MAN and Case No COMP/M.5157 - VOLKSWAGEN / SCANIA

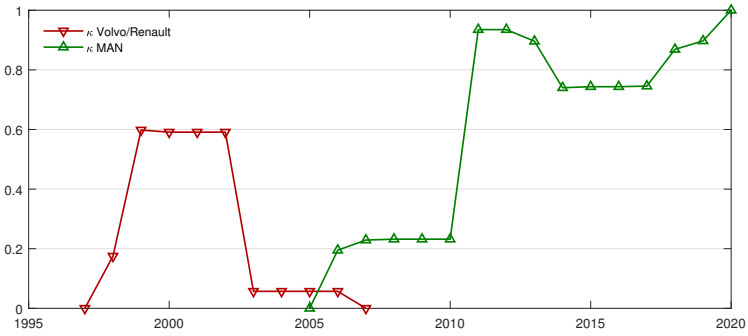


Figure 1.2: Profit weights.
Source: Own calculations based on Scania's quarterly reports.

Q_f becomes

$$Q_f = \sum_s \gamma_{fs} \pi_s, \tag{1.15}$$

with γ_{fs} denoting the weight a firm places on investor s, which is assumed to equal their voting share. After some rewriting, it can be shown that

$$Q_f \propto \pi_f + \sum_{g \neq f} \left(\underbrace{\frac{\sum_s \gamma_{fs} \beta_{gs}}{\sum_s \gamma_{fs} \beta_{fs}}}_{\kappa_{fg}} \right) \pi_g, \tag{1.16}$$

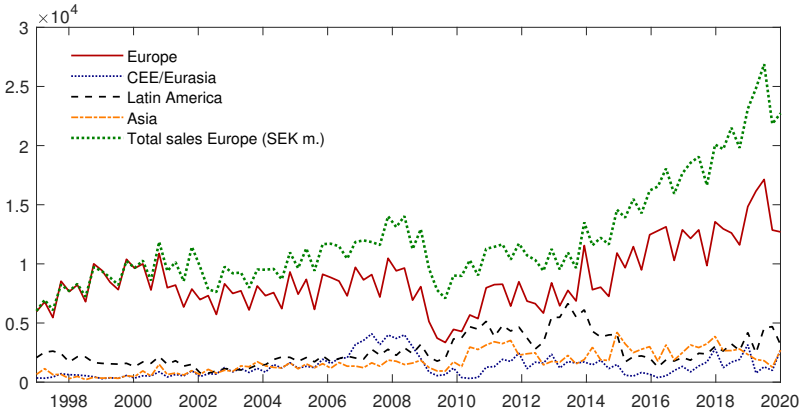
with the subscript g denoting f's competitors and proportionality resulting from κ_{ff} being normalized to one. The parameter κ_{fg} is interpreted as the relative value of a euro of profits accruing to firm g in firm f's maximization problem. If f's investors do not possess shares in any of its direct competitors, the objective function is reduced to f's profit function. Figure 1.2 depicts the profit weights obtained using equation (1.16).[12]

[12]Backus et al. (2021) leave the interpretation of the Pareto weight γ open, stating that the literature often equalizes this weight with an investors' cash-flow rights β, assuming proportional control. In Scania's case, shares consist of two categories, A and B, which yield different voting rights. I therefore differentiate between γ (voting share) and β (capital share).

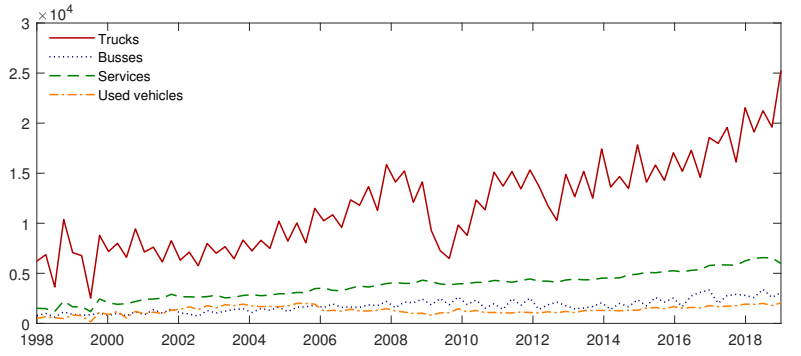
1.5 An empirical application: Scania

1.5.1 Data

Scania is a Swedish manufacturer of heavy trucks, busses and engines. Figure 1.3 provides summary information on Scania, which is mostly active on the European market, its second largest market being Latin-America, see 1.3a. During the sample period, production sites were almost exclusively located in Europe, with two exceptions in Argentina and Brazil, which supplied the Latin-American market. Scania's main source of revenue is the production and sale of heavy trucks, as shown on 1.3b.



(a) Scania's unit sales of heavy trucks by geographic market, 1997-2021.



(b) Scania sales disaggregated by product category (SEK m.), 1998-2019.

Figure 1.3: Scania at a glance.
Source: Scania's quarterly reports.

Table 1.1: Summary Statistics.
Source: Scania's quarterly reports.

Variable	Obs.	Mean	Standard Deviation	Min.	Max.
Trucks	92	8749.95	2667.16	3354	17139
Market Share (%)	92	14.81	1.55	12.9	19.4
Sales European theatre (SEK m.)	92	12078.86	4386.57	6027	26883
COGS (SEK m.)	92	14573.52	5544.95	7010	29927
COGS/vehicle (SEK m.)	92	.86	0.14	0.61	1.25

The data used in this chapter primarily comes from Scania's quarterly and anual reports. The sample used in the analysis consists of quarterly observations from 1997-2019, which yields a total of 92 observations over time for each variable. Table 1.1 provides summary statistics on the main variables.

The number of heavy trucks sold on the European market and Scania's European market share on this segment are reported on a quarterly basis. When it comes to Scania's sales, the numbers are geographically disaggregated but not at the product level. I therefore use European sales revenue as a proxy for the sales generated by heavy trucks, as I am mainly interested in changes over time. As a result, it is implicitly assumed that any sudden increase in sales relative to the number of trucks sold during the collusive period is due to higher truck prices.

When looking at overall sales disaggregated across product categories (fig. 1.3b), it can be seen there are no dramatic shifts in sales over time for the other products and that trucks make up the bulk of sales. Moreover, 1.3a depicts total sales on the European market in SEK m., which is highly correlated (0.88) with the number of trucks sold in Europe, suggesting that truck sales were indeed largely responsible for variations in sales. This is further solidified by a high correlation between the total revenue from truck sales and the total revenue on the European market (0.9).

Although costs are not dissaggregated across markets, I obtain a measure of average expenditure by dividing cost of goods sold (COGS) - which excludes transportation and other overhead costs - by the total number of Scania vehicles sold, as production primarily takes place in Europe.

1.5.2 Methodology

A switching regression

Scania's competitive conduct is examined using a switching regression model as employed by Porter (1983), who investigated the pricing behavior of a railroad cartel. In this type of model, it is assumed that a sample of observations is generated by two or more distinct regression equations or 'regimes'. Consider a sample of T observations, with r_1 and r_2 indicating which regime holds, such that

$$y_t = \begin{cases} \sum_{i=1}^{k} \beta_{1i} x_{it} + u_{1t} & \forall t \in r_1, \\ \sum_{i=1}^{k} \beta_{2i} x_{it} + u_{2t} & \forall t \in r_2. \end{cases}$$

Under unknown sample separation, it is not known which observations were generated by which regime. Let the probability of each regime occuring be governed by a Bernoulli distribution

$$t \in \begin{cases} r_1 & \text{with probability } \lambda, \\ r_2 & \text{with probability } 1-\lambda. \end{cases}$$

Assuming that u_{1t} and u_{2t} are normally distributed, with $N(0, \sigma_1^2)$ and $N(0, \sigma_2^2)$, the probability of observing y_t can be written as

$$f(y_t|x_{1t}, ..., x_{kt}) = \frac{\lambda}{\sqrt{2\pi}\sigma_1} \exp\Big(-\frac{1}{2\sigma_1^2}(y_t - \sum_{i=1}^{k} \beta_{1i} x_{it})^2 \Big) + \frac{1-\lambda}{\sqrt{2\pi}\sigma_2} \exp\Big(-\frac{1}{2\sigma_2^2}(y_t - \sum_{i=1}^{k} \beta_{2i} x_{it})^2 \Big), \quad (1.17)$$

yielding the log-likelihood function

$$\mathcal{L} = \sum_{t=1}^{T} \ln\Big(f(y_t|x_{1t}, ..., x_{kt}) \Big). \quad (1.18)$$

If λ is observed, the parameters of the model can be estimated by maximizing (1.18). If not, an algorithm proposed by Kiefer (1980) can be employed, which allows for simultaneous estimation of the regression parameters and regime probabilities. Starting from an initial guess on the sequence of regimes that generated the sample $w^0 = \{w_1^0, ..., w_T^0\}$, with w_t^0 denoting the probability that $t \in r_1$, an initial guess for

λ is obtained

$$\lambda^0 = \sum_{t=1}^{T} \frac{w_t^0}{T}. \tag{1.19}$$

Maximizing the likelihood function using λ^0 yields initial estimates for the regression parameters, denoted Ω^0. The sequence w^0 is then updated using Bayes' rule. Under this new sequence w^1 (and the corresponding posterior λ^1), updated parameter estimates are obtained (Ω^1). This procedure can be iterated until a convergence criterion is satisfied.

A baseline specification

Based on equation (1.13), the following regression equation is proposed

$$p_t = \theta^{-1} S_{it} + \sum_{k \in F_f} \sigma_{kt} \sum_{j \in F_f} a_{kj}^{-1} q_{jt} + \beta_1 \mathbb{I}_t + \beta_2 GR_t + \beta_3 R_t + u_t. \tag{1.20}$$

The binary variable $\mathbb{I}_t$ is governed by the following distribution

$$\mathbb{I}_t = \begin{cases} 1 & \text{with probability } \lambda, \\ 0 & \text{with probability } 1 - \lambda, \end{cases}$$

meaning the switch in regimes is entirely reflected via this term.

Equation (1.20) includes two dummy variables, R_t and GR_t, which coincide with the early 2000s recession and the great recession respectively. Apart from the fact that recessions are hypothesized to influence the target price set by cartels, e.g. Green and Porter (1984) and Rotemberg and Saloner (1986), inclusion is motivated by the observed increase in revenue per vehicle sold during both recessions. The dummies are switched on during these spikes.

As a further motivating point for inclusion of these dummies, it has also been acknowledged that certain inputs do not necessarily behave as variable inputs during recessions, meaning firms might no longer be minimizing costs. One example is labour, where due to hiring and firing costs firms might be encouraged to keep employees on the payroll until the cycle turns up again. This is also referred to as labour hoarding, see for instance Blanchard and Portugal (2001). As a result, recessions might falsely suggest the presence of regime shifts even though firms still behave as profit-maximizers, as in this case the cost-minimization assumption would be violated.

Production In order to estimate conduct, it is necessary to specify parametric forms for all unobservables. Following De Loecker, Eeckhout, et al. (2020), I use COGS as expenditure on a variable input bundle. For expository purpose, the output elasticity is modelled as a single parameter which is kept fixed over time. It should be noted that apart from changes in the output elasticity due to changes in productivity over time, output elasticities might change when a cartel is formed in the presence of non-constant returns to scale. If a cartel reduces output, input usage presumably decreases as well. As a consequence, output elasticities could increase (decrease) given the presence of decreasing (increasing) returns to scale.

Nonetheless, De Loecker, Eeckhout, et al. (2020) found that - using a similar specification - these elasticities varied very little over time and changes in the average elasticity for the US manufacturing sub-sector which includes commercial vehicles (NAICS33) were negligible.[13] Overall, most research suggests that variation in output elasticities over the timeframe considered is limited (De Loecker, 2021).

Demand On the demand side, I employ a logit specification, which is the workhorse model of the discrete choice literature.[14] Ivaldi and Verboven (2005) use a nested logit model to estimate demand elasticities on the truck market, distinguishing between tractor and trailer trucks. As discussed previously, such segmentation was later deemed to be incorrect as trucks fall into three categories: heavy, medium and light. In addition to this, the authors were not able to reject the hypothesis of symmetric competition between the two segments (or nests). Without differentiation, the nested logit model reduces to an ordinary logit model.

The logit model yields a well known closed-form solution for the own- and cross-price derivative of each product i

$$\frac{\partial q_{it}}{\partial p_{jt}} \equiv \mathrm{M}_t \frac{\partial s_{it}}{\partial p_{jt}} = \begin{cases} -\mathrm{M}_t \frac{\alpha}{\rho_t} s_{it}(1 - s_{it}) & \text{if } i = j, \\ \mathrm{M}_t \frac{\alpha}{\rho_t} s_{it} s_{jt} & \text{otherwise.} \end{cases} \tag{1.21}$$

The variable s_i denotes the market share of alternative i on the total market for heavy trucks, denoted as M.[15] Multiplying the change in market share with total

[13] see De Loecker, Eeckhout, et al. (2020), online appendix

[14] The logit model suffers from a number of important drawbacks. The closed-form expressions from (1.21) imply that when two products have an identical market share, the cross-price elasticity from a third product with respect to both will be the same. This can be regarded as an undesirable byproduct of the model, as a higher degree of substitution towards products which share certain characteristics would be expected. Additionally, consumer heterogeneity only enters the model via the error term, meaning all consumers have identical valuations of product characteristics.

[15] I assume the market for trucks is linked to the demand for freight transport on the European

Table 1.2: List of variables.

p_t	Real sales revenue divided by vehicles sold on the European market.
S_{it}	Real COGS per Scania vehicle produced.
s_{jt}	European market share of product j.
ρ_t	EU28 industrial PPI.
κ_{gt}	Weight placed on g's profits resulting from common- and cross-ownership.
$\mathbb{I}_t$	Collusive dummy variable.
GR_t	Dummy variable switched on during great recession; $GR_t = 1$ if $t = 46, ..., 53$. $GR_t = 0$ otherwise.
R_t	Dummy variable switched on during early 2000s recession; $R_t = 1$ if $t = 18, ..., 21$. $R_t = 0$ otherwise.

market size yields the change in output. The parameter α denotes consumer price sensitivity. This parameter is kept fixed over time, and is therefore deflated using the EU28 industrial PPI, denoted ρ.

Substituting the parametric specifications into (1.20) yields

$$p_t = \theta^{-1} S_{it} + \rho_t \left(\alpha(1 - \sum_{j \in \mathcal{F}_f} s_{jt} - \sum_g \kappa_{gt} \sum_{j \in \mathcal{F}_g} s_{jt}) \right)^{-1} + \beta_1 \mathbb{I}_t + \beta_2 GR_t + \beta_3 R_t + u_t. \tag{1.22}$$

For the derivation, see appendix A.4. A description of each variable included in this regression is given in table 1.2.[16] The previously discussed algorithm allows for the simultaneous estimation of the regime probabilities (w and λ) and regression parameters ($\alpha, \theta, \beta_1, \beta_2, \beta_3$). Similar to Porter (1983), the stopping criterion is given by a correlation of 0.999 between two successive iterations of w. As an initial guess w^0, a vector of alternating zeros and ones was employed.

1.5.3 Main results

Estimation results are displayed in table 1.3. Each equation is estimated twice, once including and once excluding ownership from Scania's objective function. Hypothesis tests were performed using a Wald test. In addition, a likelihood ratio test was performed under the null hypothesis that the data was generated by a single regime ($H_0 : \beta_1 = 0$). For the corresponding p-values, see the bottom row of table 1.3.

market, which is reported annually by Eurostat. The outside good then consists of other modes of freight transport, mainly railroads and inland waterways. Overall, the percentage of freight transported using heavy trucks (by weight) over the sample period was constant at 75%, which implies a total market ±1.33 times as large as the observed heavy truck market.

[16] When ownership is included, MAN and Volvo's quarterly market shares are calculated from annual market shares using cubic spline interpolation.

Table 1.3: Estimation results.

	No ownership weights				**With ownership weights**			
Parameters	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
θ	0.84***	0.89***	0.96***	0.95***	0.76***	0.77***	0.91***	0.90***
	(0.11)	(0.14)	(0.11)	(0.11)	(0.10)	(0.10)	(0.11)	(0.12)
α	3.60***	3.58**	2.98***	3.07***	6.03**	8.01	3.76***	3.91***
	(0.09)	(0.13)	(0.09)	(0.09)	(0.08)	(0.11)	(0.09)	(0.10)
β_1		0.12***	0.11***	0.11***		0.13***	0.11***	0.11***
		(0.04)	(0.03)	(0.03)		(0.03)	(0.04)	(0.04)
β_2			0.19***	0.19***			0.20***	0.20***
			(0.03)	(0.03)			(0.03)	(0 .04)
β_3				-0.02				-0.03
				(0.04)				(0.04)
Observations	92	92	92	92	92	92	92	92
p-value		3.74e-04	0.006	0.006		5.94e-04	0.003	0.003
BIC		22.98	22.69	22.68		23.05	22.75	22.74

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, standard errors in parentheses.

Parameter estimates With the exception of the early 2000s recession, the sign on each coefficient conforms to expectations. However, the effect of the early 2000s recession does not seem to be statistically significant. The results are more significant when ownership is not included, although the hypothesis that the data is generated by a single regime is rejected for each specification at the 1% significance level. The table further reports the Bayesian Information Criterion (BIC) for each model specification, in order to assess if one outperforms the other. As can be seen, the values are almost identical.

It should be noted that there exist well-known endogeneity issues when estimating demand, see for instance Berry et al. (1995). Similarly, the estimation of output elasticities faces a number of important pitfalls, see Ackerberg et al. (2015), Bond et al. (2021) or Raval (2023). However, given the purpose of the methodology, the magnitude of the estimates is of secondary importance, as it is mainly the model fit over time which is of interest. In this sense, the methodology can be classified as a structural break test, which attempts to discover abrupt changes in firm behavior over time in order to detect changes in competitive conduct.

In order the assess the plausibility of the parameter estimates, they are used to calculate Scania's corresponding markup estimate in the fist quarter of 1997. This figure can in turn be compared to markup estimates within comparable sectors at a similar time from the economic literature. Marginal cost estimates at time

Table 1.4: Comparison of estimates.

	$\hat{\mu}$
No ownership weights	1.35-1.46
With ownership weights	1.13-1.40
Ivaldi and Verboven (2005)	1.53-2.27
Hausman and Leonard (2005)	1.3
Konings et al. (2001)	1.3-1.45

$t = 1997 : q1$ can be recovered as either

$$\hat{c}_t = p_t - \rho_t \left(\hat{\alpha}(1 - \sum_{j \in \mathcal{F}_f} s_{jt} - \sum_g \kappa_{gt} \sum_{j \in \mathcal{F}_g} s_{jt}) \right)^{-1}, \tag{1.23}$$

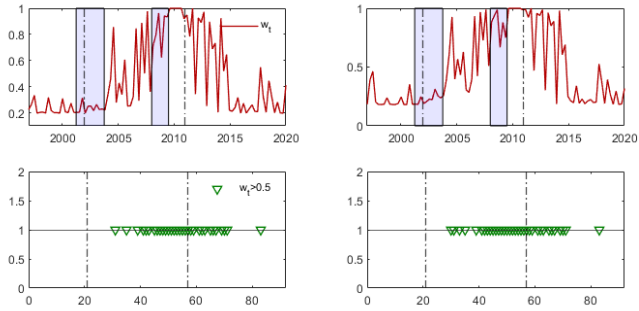
or

$$\hat{c}_t = \hat{\theta}^{-1} S_{it}, \tag{1.24}$$

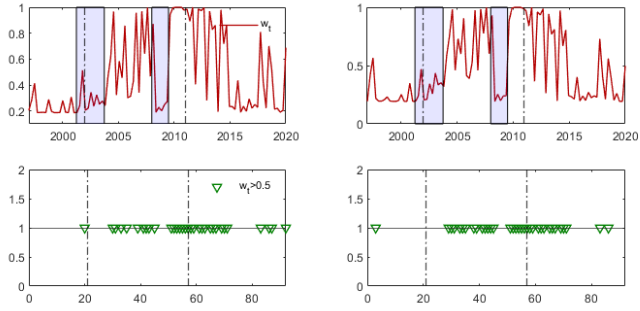
which in turn can be used to calculate the corresponding markups. In table 1.4, markup estimates are presented which are obtained using parameter estimates of the full model, but once including and once excluding ownership weights. These figures are constrasted with estimates from the economic literature.

In previous work on the trucking industry in 1997, Ivaldi and Verboven (2005) used a nested logit model to estimate markups of price over marginal cost. Their estimates ranged from 1.53 to 2.27 for the different national markets. Hausman and Leonard (2005) disagreed with these findings, suggesting that industry data, which implied a markup of 1.3, seemed more realistic. A similar figure was found by Konings et al. (2001) for the broader motor vehicles, trailers and semi-trailers sector in 1995, with a markup of 1.3 in Belgium and 1.45 in the Netherlands.

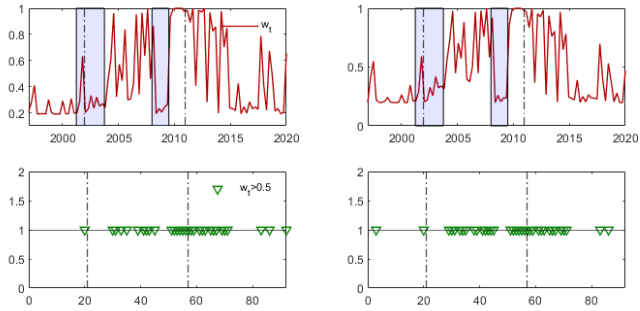
The estimates are in a plausible range regardless of the regression specification, as neither seems to deliver unrealistic estimates. When ownership is included, the estimates range from 1.13 to 1.40. When ownership is excluded, estimates are overall higher, ranging between 1.35-1.46. In the case of COGS, Syverson (2019) also notes that the output elasticity can be re-interpreted as the scale elasticity, meaning an estimate of θ (below) 1 implies increasing (decreasing) returns to scale. In this sense, the scale elasticity seems to be somewhat on the low side when ownership is included, see table 1.3, although this difference becomes negligible when a dummy is included for the Great Recession.



(a) Regime probabilities without recession dummies.



(b) Regime probabilities with Great Recession dummy.



(c) Regime probabilities with both recession dummies.

Figure 1.4: Regime probabilities, without (left) and with ownership weights (right).

Regime probabilities When included, β_1 is positive and implies a regime switch which caused a sizable price increase as the dependent variable is reported in million SEK. Figure 1.4 depicts the value of w over time for each regression, which represents the probability that an observation belongs to the collusive regime. The dashed vertical lines demarcate the period from the introduction of the Euro to the official end of the cartel, and the shaded areas denote recessions. Interestingly, for all specifications there is a clear increase in this probability from 2001 onwards followed by a decrease post-2011.

The results seem stronger when the GR dummy is included. If the model fit changes during the recession and it no longer tracks the data, perhaps due to firms no longer minimizing costs, these changes might be interpreted as a regime change on its own, thereby muddling the picture. Once a dummy is included, it can be seen that more observations are attributed to the collusive regime. Following Lee and Porter (1984), each observation is classified to a regime using the rule

$$\hat{\mathbb{I}}_t = \begin{cases} 1 & \text{if } \hat{w}_t > 0.5 \\ 0 & \text{if } \hat{w}_t \leq 0.5 \end{cases}$$

For each specification, the bottom panel shows the observations which are classified as collusive. Almost all observations categorized as such lie within the timeframe over which the cartel was active according to the EC. After the formation of the cartel, there is no immediate divergence between marginal costs. This is not unexpected given the EC's timeline and not unusual as anti-competitive effects caused by a cartel do not necessarily coincide with the formal cartel dates as collusive agreements often require some time to take effect (Boswijk et al., 2019).

The most interesting takeaways are that (i) marginal costs start to diverge from 2001 onwards, which is consistent with the EC timeline, (ii) the wedge starts to decrease as soon as the cartel is discovered and (iii) there is a post-cartel convergence. This convergence is not immediate but rather gradual. However, it is not uncommon for prices to stay above the competitive level in the post-cartel period due to some form of lingering tacit collusion (Chowdhury and Crede, 2020).

A conduct parameter It is possible to obtain an estimate of the conduct parameter ϕ, which denotes the weight placed on other firms' profits as described in equation (1.1). In the case of joint-profit maximization $\phi = 1$, although Levenstein and Suslow (2006) point out that it is not uncommon for collusive prices to be set

Table 1.5: Estimation results.

Parameters	(1)	(2)
θ	2.02***	1.02***
	(0.07)	(0.09)
α	1.20***	2.06***
	(0.06)	(0.08)
β_1		-0.43***
		(0.13)
β_2	0.32***	0.26***
	(0.03)	(0.03)
Observations	92	92

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, Standard errors in parentheses.

below or even above the monopoly price. Introducing a conduct parameter which is constant across all competitors yields the following equation

$$p_t = \theta^{-1} S_{it} + \rho_t \left(\alpha (1 - \sum_{j \in \mathcal{F}_f} s_{jt} - \mathbb{I}_t \beta_1 \sum_{g \in \mathcal{G}} s_{gt}) \right)^{-1} + \beta_2 GR_t + u_t. \tag{1.25}$$

If the variable $\mathbb{I}_t$ equals 1 in the cooperative regime and 0 under competition, then

$$\hat{\phi}_t = \hat{\beta}_1 \hat{w}_t. \tag{1.26}$$

For the derivation, see appendix A.4. The set $\mathcal{G}$ is assumed to consist of all other firms. Parameter estimates are given in table 1.5.

The results are similar to those obtained using the baseline model, although the algorithm in this case resulted in the dummy variable $\mathbb{I}$ being switched on during the competitive regime, yielding a negative estimate on the coefficient β_1. The interpretation is still the same, as this implies that Scania placed more weight on its competitors' profits during the cartel period. Figure 1.5 compares the fitted values of p for both regimes when a conduct parameter is introduced with the actual data, with

$$\hat{p}_t = \hat{\theta}^{-1} S_{it} + \hat{\beta}_2 GR_t + \begin{cases} \rho_t \left(\hat{\alpha} (1 - \sum_{j \in \mathcal{F}_f} s_{jt} - \mathbb{I}_t \hat{\beta}_1 \sum_{g \in \mathcal{G}} s_{gt}) \right)^{-1} & \text{(Regime 1)}, \\ \rho_t \left(\hat{\alpha} (1 - \sum_{j \in \mathcal{F}_f} s_{jt}) \right)^{-1} & \text{(Regime 2)}. \end{cases}$$

As can be seen from this image, the model does track the data well given the

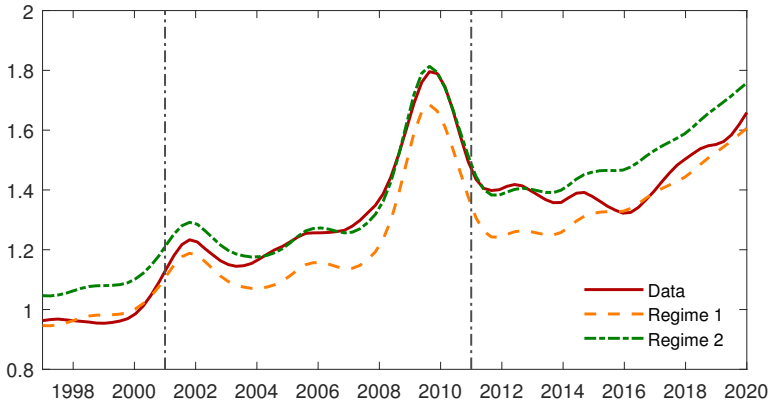


Figure 1.5: Fitted values compared to the data, smoothed.

assumption that a regime switch took place between 2001 and 2011. The fitted values from Regime 1 (the competitive regime) fit the data reasonably well during the non-collusion period but under-estimate Scania's prices during the collusion period; the fitted values from Regime 2 (the collusive regime) fit the data well during the collusive period but over-estimate Scania's prices during the non-collusion period.

1.5.4 Penalization

The framework employed in this chapter could serve a purpose in cartel penalization. In both competition enforcement and private claims, damages are often estimated using a counterfactual price estimate, i.e. the price charged in the hypothetical scenario where an infringement did not take place. The post-cartel price is frequently used as a competitive benchmark.

In order to avoid under-penalization, it is therefore important to establish when anti-competitive effects took place. As mentioned previously, it is not uncommon for prices to stay above the competitive level in the post-cartel period due to some form of lingering collusion, leading to overestimation of the counterfactual price. For instance, Connor (2001) notes that in the citric acid cartel, prices persisted at a higher level up to eighteen months after the breakdown of collusion. For a more elaborate discussion on 'post-cartel tacit collusion', see Chowdhury and Crede (2020). In addition to this, Harrington Jr (2004) notes that using the post-cartel period as a competitive benchmark could incentivize firms to artificially inflate prices during

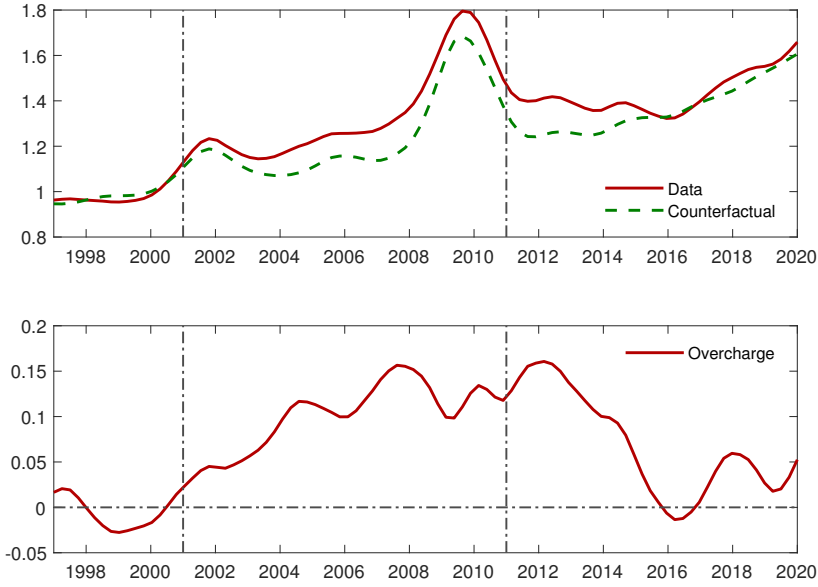


Figure 1.6: Counterfactual price and the associated overcharge.

litigation, resulting in a lower estimate of the damages.

Lastly, Boswijk et al. (2019) consider that injured parties are entitled to compensation for any harm caused by and following the infringement, i.e. prices lingering above the competitive level after cartel detection. As a result, establishing when pricing is competitive becomes a necessity. Figure 1.5 suggests that although prices reverted to the competitive level soon after the cartel was discovered, convergence was not immediate, which might bias any damage estimates obtained using post-2011 data.

In the US, it is standard practice to determine the size of fines given to collusive firms using an estimate of the counterfactual price. Clark et al. (2004) define the counterfactual as the hypothetical scenario where an antitrust infringement did not occur but conditions are otherwise similar. The counterfactual price is therefore the price which would be set under competitive behavior given the observed economic reality determined by - among others - market shares, consumer demand and productivity. As a result, the counterfactual price is also called the but-for price, i.e. the price which would be charged but for collusion. Ideally, one would try to

find both competitive quantities and prices as collusion tends to result in reduced output. However, it is common in legal cases to use observed quantities as a basis and only focus on estimating the competitive price (Seixas and Lucinda, 2019). A simplified version of the formula used in US antitrust practice to calculate cartel damages is given by Harrington Jr (2004)

$$\text{Cartel Damages}(t) = \Big(p_t - \hat{p}_t\Big) q_t(p_t), \tag{1.27}$$

with p_t and $\hat{p}_t$ denoting the price charged by a firm in the observed and counterfactual scenario respectively. Demand q is a function of the observed price, meaning it is the observed sales quantity. The difference between the actual and counterfactual price is called the the cartel overcharge.

Based on the previously discussed framework, it is possible to obtain an estimate of the overcharge. Using the predicted price under the competitive regime, which is depicted on figure 1.5, as a counterfactual estimate $\hat{p}_t$, figure 1.6 depicts the predicted overcharge. As can be seen on this figure, using the post-2011 price as a competitive benchmark could result in a downward estimate on total damages, while simultaneously ignoring part of the overcharge incurred in the post-cartel period. As sales are reported in million SEK, this figure further suggests that the cartel caused a sizable increase in price. Lastly, given that the results presented here are reliable, they indicate the presence of significant post-cartel tacit collusion in the truck industry, as Scania's behavior remained inconsistent with that of an own-profit maximizer for close to five years after the end of the cartel.

1.6 Conclusion

This chapter presented a framework to detect a change in Scania's objective function, in order to discern between active collusion and free riding. Evidence was found which supports the EC's claim that Scania was part of the cartel. Using a switching regression, it is shown that during the collusive period, marginal costs obtained under the dual assumptions of profit-maximization and cost-minimization diverged, which in turn might indicate that Scania was no longer maximizing its own profits. In the case of cartel prosecution, this could therefore qualify as an action against self-interest, providing evidence against Scania's line of argumentation. While the presence of parallel conduct is insufficient to demonstrate that Scania was part of the cartel, the absence of own-profit maximization can be considered evidence which

satisfies a higher standard of proof.

Furthermore, it is demonstrated how a similar framework might be of use in the penalization phase, as it allows for the calculation of counterfactual terms without relying on post-cartel prices as a competitive benchmark. In this sense, the proposed method is not exposed to a downward bias which might be introduced if the cartel price remains above the competitive level after discovery.

Bibliography

Ackerberg, Daniel A, Kevin Caves, and Garth Frazer (2015). "Identification properties of recent production function estimators". In: *Econometrica* 83.6, pp. 2411–2451.

Ashenfelter, Orley C, Daniel S Hosken, and Matthew C Weinberg (2015). "Efficiencies brewed: pricing and consolidation in the US beer industry". In: *The RAND Journal of Economics* 46.2, pp. 328–361.

Backus, Matthew, Christopher Conlon, and Michael Sinkinson (2021). "Common ownership in America: 1980–2017". In: *American Economic Journal: Microeconomics* 13.3, pp. 273–308.

Baker, Jonathan B (1993). "Two Sherman Act Section 1 dilemmas: parallel pricing, the oligopoly problem, and contemporary economic theory". In: *The Antitrust Bulletin* 38.1, pp. 143–219.

Berry, Steven, James Levinsohn, and Ariel Pakes (1995). "Automobile prices in market equilibrium". In: *Econometrica*, pp. 841–890.

Beyer, Christian, Elke Kottmann, and Korbinian von Blanckenburg (2020). "The welfare implications of the European trucks cartel". In: *Intereconomics* 55.2, pp. 120–126.

Blanchard, Olivier and Pedro Portugal (2001). "What hides behind an unemployment rate: Comparing Portuguese and US labor markets". In: *American Economic Review* 91.1, pp. 187–207.

Bond, Steve, Arshia Hashemi, Greg Kaplan, and Piotr Zoch (2021). "Some unpleasant markup arithmetic: Production function elasticities and their estimation from production data". In: *Journal of Monetary Economics* 121, pp. 1–14.

Boswijk, H Peter, Maurice JG Bun, and Maarten Pieter Schinkel (2019). "Cartel dating". In: *Journal of Applied Econometrics* 34.1, pp. 26–42.

Chowdhury, Subhasish M and Carsten J Crede (2020). "Post-cartel tacit collusion: Determinants, consequences, and prevention". In: *International Journal of Industrial Organization* 70, p. 102590.

Ciliberto, Federico and Jonathan W Williams (2014). "Does multimarket contact facilitate tacit collusion? Inference on conduct parameters in the airline industry". In: *The RAND Journal of Economics* 45.4, pp. 764–791.

Clark, Emily, Mat Hughes, and David Wirth (2004). "Study on the conditions of claims for damages in case of infringement of EC competition rules-Analysis of economic models for the calculation of damages". In: *Ashurst, Brussels*.

Connor, John M (2001). ""Our customers are our enemies": the lysine cartel of 1992–1995". In: *Review of Industrial Organization* 18.1, pp. 5–21.

Crede, Carsten J (2019). "A structural break cartel screen for dating and detecting collusion". In: *Review of Industrial Organization* 54.3, pp. 543–574.

d'Aspremont, Claude, Alexis Jacquemin, Jean Jaskold Gabszewicz, and John A Weymark (1983). "On the stability of collusive price leadership". In: *Canadian Journal of economics*, pp. 17–25.

De Loecker, Jan (2021). "Comment on (Un) pleasant... by Bond et al (2020)". In: *Journal of Monetary Economics*.

De Loecker, Jan, Jan Eeckhout, and Gabriel Unger (2020). "The rise of market power and the macroeconomic implications". In: *The Quarterly Journal of Economics* 135.2, pp. 561–644.

De Loecker, Jan, Pinelopi K Goldberg, Amit K Khandelwal, and Nina Pavcnik (2016). "Prices, markups, and trade reform". In: *Econometrica* 84.2, pp. 445–510.

De Loecker, Jan and Paul T Scott (2016). *Estimating market power Evidence from the US Brewing Industry*. Tech. rep. National Bureau of Economic Research.

De Loecker, Jan and Frederic Warzynski (2012). "Markups and firm-level export status". In: *American economic review* 102.6, pp. 2437–71.

Deneckere, Raymond and Carl Davidson (1985). "Incentives to form coalitions with Bertrand competition". In: *The RAND Journal of economics*, pp. 473–486.

Genesove, David and Wallace P Mullin (1998). "Testing static oligopoly models: conduct and cost in the sugar industry, 1890-1914". In: *The RAND Journal of Economics*, pp. 355–377.

Gilo, David, Yossi Moshe, and Yossi Spiegel (2006). "Partial cross ownership and tacit collusion". In: *The Rand journal of economics* 37.1, pp. 81–99.

Green, Edward J and Robert H Porter (1984). "Noncooperative collusion under imperfect price information". In: *Econometrica: Journal of the Econometric Society*, pp. 87–100.

Harringon, Joseph E (2008). "Detecting Cartels". In: *Handbook of Antitrust Economics* 1, pp. 213–258.

Harrington Jr, Joseph E (2004). "Post-cartel pricing during litigation". In: *The Journal of Industrial Economics* 52.4, pp. 517–533.

Hausman, Jerry A and Gregory K Leonard (2005). "Using merger simulation models: Testing the underlying assumptions". In: *International Journal of Industrial Organization* 23.9-10, pp. 693–698.

Ivaldi, Marc and Frank Verboven (2005). "Quantifying the effects from horizontal mergers in European competition policy". In: *International Journal of Industrial Organization* 23.9-10, pp. 669–691.

Kiefer, Nicholas M (1980). "A note on switching regressions and logistic discrimination". In: *Econometrica: Journal of the Econometric Society*, pp. 1065–1069.

Kim, H Youn (1987). "Economies of scale in multi-product firms: an empirical analysis". In: *Economica*, pp. 185–206.

Konings, Jozef, Patrick Van Cayseele, and Frederic Warzynski (2001). "The dynamics of industrial mark-ups in two small open economies: does national competition policy matter?" In: *International Journal of Industrial Organization* 19.5, pp. 841–859.

Kovacic, William E, Robert C Marshall, Leslie M Marx, and Halbert L White (2011). "Plus factors and agreement in antitrust law". In: *Mich. L. Rev.* 110, p. 393.

Lee, Lung-Fei and Robert H Porter (1984). "Switching Regression Models with Imperfect Sample Separation Information–With an Application on Cartel Stability". In: *Econometrica: Journal of the Econometric Society*, pp. 391–418.

Levenstein, Margaret C and Valerie Y Suslow (2006). "What determines cartel success?" In: *Journal of economic literature* 44.1, pp. 43–95.

Miller, Nathan H and Matthew C Weinberg (2017). "Understanding the price effects of the MillerCoors joint venture". In: *Econometrica* 85.6, pp. 1763–1791.

Nevo, Aviv (2001). "Measuring market power in the ready-to-eat cereal industry". In: *Econometrica* 69.2, pp. 307–342.

Panzar, John C and Robert D Willig (1977). "Economies of scale in multi-output production". In: *The Quarterly Journal of Economics*, pp. 481–493.

Porter, Robert H (1983). "A study of cartel stability: the Joint Executive Committee, 1880-1886". In: *The Bell Journal of Economics*, pp. 301–314.

Raval, Devesh (2023). "Testing the production approach to markup estimation". In: *Review of Economic Studies* 90.5, pp. 2592–2611.

Reiss, Peter C and Frank A Wolak (2007). "Structural econometric modeling: Rationales and examples from industrial organization". In: *Handbook of econometrics* 6, pp. 4277–4415.

Rotemberg, Julio J and Garth Saloner (1986). "A supergame-theoretic model of price wars during booms". In: *The American economic review* 76.3, pp. 390–407.

Seixas, Renato Nunes de Lima and Claudio Ribeiro de Lucinda (2019). "Computing Cartel Overcharges: when theory meets practice". In: *Estudos Econômicos (São Paulo)* 49.3, pp. 569–599.

Syverson, Chad (2019). "Macroeconomics and market power: Context, implications, and open questions". In: *Journal of Economic Perspectives* 33.3, pp. 23–43.

Werden, Gregory J (2003). "Economic evidence on the existence of collusion: Reconciling antitrust law with oligopoly theory". In: *Antitrust LJ* 71, p. 719.

Appendix A

Appendix Chapter 1

A.1 Strict diagonal dominance

Consider a demand system for trucks on the European market $\mathbf{q} = q_1, ..., q_J$. Denote the Jacobian of demand as $\mathbf{J}$. It is assumed that trucks are both normal goods and imperfect substitutes, implying a negative diagonal and a positive off diagonal. It is assumed that when the price of one model increases, some demand leaves the market, meaning $\mathbf{J}$ is a strictly diagonally dominant matrix.

definition 1. (Strict Diagonal Dominance). *A matrix* $\mathbf{C}$ *of order* n *is strictly diagonally dominant if*

$$|c_{ii}| > \sum_{j \neq i} |c_{ij}|$$

for each row $i = 1, ..., n$.

A.2 Proof proposition 1

Using the previously specified objective function (2.1), a Bertrand-Nash equilibrium under flexible conduct is characterized by the following system

$$\mathbf{c} = (\mathbf{A} + \phi\mathbf{B})^{-1}\mathbf{s} + \mathbf{p}, \tag{A.1}$$

with $\mathbf{c}$, $\mathbf{s}$ and $\mathbf{p}$ denoting $J \times 1$ vectors of cost, market share and price. $\mathbf{A}$ and $\mathbf{B}$ are $J \times J$ matrices with

$$a_{ij} = \begin{cases} \frac{\partial s_j}{\partial p_i} & \text{if } \exists f : \{i,j\} \subset \mathcal{F}_f, \\ 0 & \text{otherwise;} \end{cases} \qquad b_{ij} = \begin{cases} \frac{\partial s_j}{\partial p_i} & \text{if } \nexists f : \{i,j\} \subset \mathcal{F}_f, \\ 0 & \text{otherwise.} \end{cases}$$

If a firm f is assumed to maximize its own profits but instead is part of a cartel, marginal costs are upwardly biased. I show this to be the case for the situation in which all firms are part of the cartel, but the results can easily be generalized to other specifications with different profit weights across competitors and products.

Proposition 1. *Given the assumptions made in appendix C.1, then*

$$(\mathbf{A} + \phi_1 \mathbf{B})^{-1}\mathbf{s} > (\mathbf{A} + \phi_2 \mathbf{B})^{-1}\mathbf{s},$$

if $\phi_1 < \phi_2$*, with* $\phi_1, \phi_2 \in [0, 1]$.

Proof. First, we are interested in proving the following inequality

$$\mathbf{A}^{-1}\mathbf{s} > (\mathbf{A} + \phi \mathbf{B})^{-1}\mathbf{s}, \tag{A.2}$$

where $\mathbf{A}$ is strictly diagonally dominant with a negative diagonal, $\mathbf{B}$ is such that $\mathbf{A} + \mathbf{B}$ is also negative strictly diagonally dominant, $0 < \phi \leq 1$ and $0 < s_j < 1 \; \forall j$. Negating both sides flips the inequality

$$\bar{\mathbf{A}}^{-1}\mathbf{s} < (\bar{\mathbf{A}} + \phi \bar{\mathbf{B}})^{-1}\mathbf{s}. \tag{A.3}$$

We can then calculate the inverse of equation (2.2) using a *Neumann series*, an expansion of the form

$$(\mathbb{I}_N - \mathbf{T})^{-1} = \sum_{k=0}^{\infty} \mathbf{T}^k, \tag{A.4}$$

where $\mathbb{I}_N$ denotes the unit matrix in n dimensions. Take $\bar{\mathbf{A}} = \mathbb{I}_N - \mathbf{T}$ and the expansion becomes

$$\bar{\mathbf{A}}^{-1} = \sum_{k=0}^{\infty} \mathbf{T}^k, \tag{A.5}$$

in terms of the matrix $\mathbf{T}$. The form of $\mathbf{T}$ is known however

$$\mathbf{T} = \mathbb{I}_N - \bar{\mathbf{A}} \sim \begin{bmatrix} 0 < a_{11} < 1 & 0 \leq a_{12} < 1 & \dots \\ 0 \leq a_{21} < 1 & 0 < a_{22} < 1 & \\ \vdots & & \ddots \end{bmatrix}, \tag{A.6}$$

due to the condition of being negative diagonally dominant and the entries of $\bar{\mathbf{A}}$ being constrained to $0 < a_{ii} < 1$ and $-1 < a_{i \neq j} < 0$. The series in equation (2.3) will only converge if $||\mathbf{T}||_{\text{OP}} = ||\mathbf{T}||_2 < 1$ or $\rho(\mathbf{T}) < 1$, where $\rho = \max\lambda_i(\bar{\mathbf{A}})$ is called the *spectral radius*.

The eigenvalues of $\mathbf{T}$ are easily estimated by the *Gerschgorin circle theorem* and are at most $\max_i\{1 + a_{ii} + \sum_{j \neq i} a_{ij}\}$. Recall the property of negative diagonal dominance $|a_{ii}| > \sum_{i \neq j} |a_{ij}|$ such that $\rho(\mathbf{T}) < 1$ and the Neumann series can be calculated. The important thing to realize is that (i) all non-zero elements of the matrices are between zero and one, (ii) the expansion for $\bar{\mathbf{A}}$ has, by construction, some finite blocks of zeros and (iii) the expansions being in terms of $\mathbf{A}$ and $\mathbf{B}$ allows us to deduce that the entries common to both matrices are equal. The result follows by simply 'calculating' the powers in the expansion and realizing that for every row-column product the right hand side is neccesarily larger in equation (2.2) by construction. To prove that

$$(\mathbf{A} + \phi_1 \mathbf{B})^{-1}\mathbf{s} > (\mathbf{A} + \phi_2 \mathbf{B})^{-1}\mathbf{s} \tag{A.7}$$

note that

$$(\bar{\mathbf{A}} + \phi_1 \bar{\mathbf{B}})^{-1}\mathbf{s} < (\bar{\mathbf{A}} + \phi_2 \bar{\mathbf{B}})^{-1}\mathbf{s}, \tag{A.8}$$

and by the same reasoning above one finds matrices of the form

$$\mathbf{T} = \begin{bmatrix} 0 < a_{11} & 0 \leq \phi_1 a_{12} < 1 & \dots \\ 0 \leq \phi_1 a_{21} & 0 < a_{22} < 1 & \\ \vdots & & \ddots \end{bmatrix}, \tag{A.9}$$

for the left hand side, as well as for the right hand side with ϕ_2 instead of ϕ_1. By the same arguments as above, the right hand side must necessarily be larger.

□

A.3 Firm-level aggregation

Following De Loecker, Goldberg, et al. (2016), it is assumed multi-product firms minimize costs product-by-product and input prices are the same across products, such that in the optimum

$$c_k = \underbrace{\left(\frac{\partial q_k}{\partial v_{ki}} \frac{v_{ki}}{q_k}\right)}_{\theta_k^i}{}^{-1} \frac{p_i v_{ki}}{q_k} \quad \forall k \in \mathcal{F}_f. \tag{A.10}$$

Taking the share-weighted sum of marginal costs yields

$$\begin{aligned} \sum_{\mathcal{F}_f} c_k \sigma_k &= \frac{p_i}{q_f} \sum_{\mathcal{F}_f} \left(\frac{\partial q_k}{\partial v_{ki}} \frac{1}{q_k}\right)^{-1} \\ &= \frac{p_i}{q_f} \sum_{\mathcal{F}_f} \frac{\partial v_{ki}}{\partial q_k} q_k = \frac{p_i}{q_f} \sum_{\mathcal{F}_f} \frac{\partial v_{fi}}{\partial q_k} q_k, \end{aligned} \tag{A.11}$$

with $\frac{\partial v_{ki}}{\partial q_k}$ denoting the change in input usage along the expansion path where input prices are constant and costs are minimized. The total output of f is given by the variable q_f such that $\sigma_k = q_k/q_f$. Let v_{fi} denote total usage of input i, from which the last equality follows. Cross-multiplying the right hand side of (A.11) with v_{fi} yields

$$c_f = \underbrace{\frac{p_i v_i}{q_f}}_{S_{if}} \underbrace{\sum_{\mathcal{F}_f} \frac{\partial \ln v_i}{\partial \ln q_k}}_{\left(\theta_f^i\right)^{-1}}. \tag{A.12}$$

A local measure of the overall output elasticity of input i, denoted θ_f^i is given by the reciprocal of the sum of input elasticities of individual outputs. For a more elaborate discussion, see for instance Panzar and Willig (1977) or Kim (1987), who consider the case of overall scale elasticities, i.e. the output elasticity of total variable costs. A similar specification to (A.12) is often used in empirical work estimating marginal costs when data is observed at the firm-level, see for instance De Loecker and Warzynski (2012) or De Loecker, Eeckhout, et al. (2020).

A.4 Estimating equations

In an interior (competitive) Bertrand-Nash equilibrium, the following system of equations holds

$$\mathbf{c} = (\underbrace{\Omega \odot \mathbf{J}}_{\mathbf{A}})^{-1}\mathbf{q} + \mathbf{p}, \tag{A.13}$$

with $\mathbf{c}$, $\mathbf{q}$ and $\mathbf{p}$ denoting the $J \times 1$ vectors of marginal cost, quantity and price of all J products sold on the market. The $J \times J$ matrix $\mathbf{J}$ is the (transposed) Jacobian of demand and Ω is a $J \times J$ matrix with

$$\omega_{ij} = \begin{cases} 1 & \text{if } \exists f : \{i,j\} \subset \mathcal{F}_f, \\ 0 & \text{otherwise,} \end{cases} \tag{A.14}$$

such that the element-by-element or Hadamard product yields the $J \times J$ matrix $\mathbf{A}$, with

$$a_{ij} = \begin{cases} \frac{\partial q_j}{\partial p_i} & \text{if } \exists f : \{i,j\} \subset \mathcal{F}_f, \\ 0 & \text{otherwise.} \end{cases} \tag{A.15}$$

This system can be generalized to accommodate ownership concerns by re-writing it as

$$\mathbf{c} = (\underbrace{\Omega^* \odot \mathbf{J}}_{\mathbf{B}})^{-1}\mathbf{q} + \mathbf{p}, \tag{A.16}$$

with

$$\omega^*_{ij} = \begin{cases} 1 & \text{if } \exists f : \{i,j\} \subset \mathcal{F}_f, \\ \kappa_{gh} & \text{if } \nexists f : \{i,j\} \subset \mathcal{F}_f \text{ and } j \in \mathcal{F}_h, i \in \mathcal{F}_g, \end{cases} \tag{A.17}$$

and κ_{gh} denoting the weight placed by g on h's profits due to common-ownership. Using the closed-form solutions provided by the logit model for own- and cross-price derivatives in equation (1.21), $\mathbf{B}$ can be defined as

$$b_{ij} = \begin{cases} -\frac{\alpha}{\rho} q_i (1 - s_i) & \text{if } \exists f : \{i,j\} \subset \mathcal{F}_f \text{ and } i = j \\ \frac{\alpha}{\rho} q_i s_j & \text{if } \exists f : \{i,j\} \subset \mathcal{F}_f \text{ and } i \neq j \\ \kappa_{gh} \frac{\alpha}{\rho} q_i s_j & \text{if } \nexists f : \{i,j\} \subset \mathcal{F}_f \text{ and } j \in \mathcal{F}_h, i \in \mathcal{F}_g. \end{cases}$$

From the associative property of matrix multiplication, it follows that

$$\mathbf{B}\Big(\underbrace{\mathbf{B}^{-1}\mathbf{q}}_{\mathbf{D}}\Big) = \mathbf{q}. \tag{A.18}$$

In order for (A.18) to hold, the element on the i'th row of the $J \times 1$ vector $\mathbf{D}$ equals

$$d_i = -\left(\frac{\alpha}{\rho}(1 - \sum_{j \in \mathcal{F}_g} s_j - \sum_{j \neq g} \kappa_{gj} \sum_{k \in \mathcal{F}_j} s_k)\right)^{-1}, \tag{A.19}$$

with $i \in \mathcal{F}_g$. As a result, we know that

$$c_i = p_i - \rho\left(\alpha(1 - \sum_{j \in \mathcal{F}_g} s_j - \sum_{j \neq g} \kappa_{gj} \sum_{k \in \mathcal{F}_j} s_k)\right)^{-1}, \tag{A.20}$$

and

$$c_g = p_g - \rho\left(\alpha(1 - \sum_{j \in \mathcal{F}_g} s_j - \sum_{j \neq g} \kappa_{gj} \sum_{k \in \mathcal{F}_j} s_k)\right)^{-1}, . \tag{A.21}$$

Similarly, when introducing a conduct parameter, the matrix $\mathbf{B}$ can de defined as

$$b_{ij} = \begin{cases} -\frac{\alpha}{\rho} q_i (1 - s_i) & \text{if } i, j \ \subset \mathcal{F}_f \text{ and } i = j \\ \frac{\alpha}{\rho} q_i s_j & \text{if } i, j \subset \mathcal{F}_f \text{ and } i \neq j \\ \phi \frac{\alpha}{\rho} q_i s_j & \text{otherwise.} \end{cases}$$

In this case, it is easily shown that

$$c_i = p_i - \rho\left(\alpha(1 - \sum_{j \in \mathcal{F}_f} s_j - \phi \sum_{j \notin \mathcal{F}_f} s_j)\right)^{-1}, \tag{A.22}$$

for each $i \in \mathcal{F}_f$ and

$$c_f = p_f - \rho\left(\alpha(1 - \sum_{j \in \mathcal{F}_f} s_j - \phi \sum_{j \notin \mathcal{F}_f} s_j)\right)^{-1}. \tag{A.23}$$

2

Fringe market share as a collusive marker. Evidence from the EEA truck market.

This chapter serves as the basis for a working paper co-authored with Iwan Bos.

2.1 Introduction

The theoretical literature on collusion often assumes that if a cartel is formed, it encompasses all firms on the market. Conventional wisdom suggests that when firms agree to cooperate, this creates opportunities to undercut the collusive price and capture a larger share of the market. Should an incomplete cartel agree to fix prices, some fraction of customers will take their business elsewhere and switch to competitors who are not constrained by any agreement, thereby destabilizing the cartel.

Nonetheless, evidence from discovered cartels shows that incomplete cartels not only exist, but constitute the vast majority of all cases. In response, a number of theoretical contributions have established conditions under which cartels are stable in the presence of non-colluding outsiders, see for instance d'Aspremont et al. (1983), Donsimoni et al. (1986), Shaffer (1995) and Bos and Harrington Jr (2010). Although these contributions employ a variety of models, they all reach a similar conclusion: incomplete cartels can be stable, but will always benefit outsiders who remain free to engage in price-cutting, expanding their market share at the cartel's expense.

As the predictions regarding outsider behaviour are seemingly unanimous, it raises the following question: how might they be of use to antitrust practitioners? In order to address this question, the present chapter examines the behaviour of outsiders in an incomplete cartel. More specifically, I study the European truck cartel - which was active on the EEA market from 1997 until 2011 - with the intent of providing both an empirical underpinning for these theoretical predictions, and practical implications which could be of use to competition authorities.

Although the firms convicted of collusion on the truck market possessed a joint market share of over 90%, they still faced competition from a large number of noncartel firms. Using data on commercial vehicle registrations on the EEA market between 2001 and 2017, I examine the evolution of outsider market shares, both during and after the collusive period. In line with the theoretical predictions, it is found that these outsiders were able to maintain a higher market share when the cartel was actively colluding.

This chapter and its findings contribute to three strands of literature. Most importantly, it corroborates the theoretical literature with regards to the behaviour of non-collusive outsiders, and is to my knowledge the first dedicated (empirical) study to do so. The end of the cartel caused a sudden and persistent decrease in the outsiders' market share, suggesting that as the colluding firms started to behave in

a competitive manner, this eliminated the opportunity for price-cutting.

As a second contribution, I relate these findings to the literature on cartel detection. Porter (2005) notes that the presence of noncartel firms might offer unique opportunities to antitrust practitioners, as they can serve as a competitive benchmark. As an example, this logic is employed by Porter and Zona (1993), who detect differences between members and non-members in a bid-rigging agreement. d'Aspremont et al. (1983), Bos and Harrington Jr (2010) and Bos and Harrington Jr (2015) argue that incomplete cartels tend to consist of the largest firms on the market, meaning market shares could be of use in cartel detection.[1] When a cartel is formed, prices are expected to increase across the board. However, prices vary due to any number of reasons unrelated to collusion. Should a sudden price increase be combined with an increase in the market share of fringe firms, this could provide a clearer signal to antitrust authorities that something might be amiss.

Lastly, I discuss the potential implications of these findings for cartel prosecution. More specifically, changes in market share could be used to establish cartel participation. Should a firm deny being part of a cartel, a decrease in market share during the collusive period can provide evidence to the contrary. As an empirical example, I use this insight to provide evidence of cartel participation on behalf of Swedish truck manufacturer Scania, which denied the European Commission's (EC) charges.[2]

The rest of this chapter is structured as follows. Section 2.2 reviews the literature on both cartel stability (2.2.1) and cartel detection and prosecution (2.2.2). The main contribution follows in section 2.3, where the behaviour of a competitive fringe is examined in the presence of a cartel. In section 2.4, a potential application for the previous findings is proposed, as it presents a test aimed at establishing cartel participation. Section 2.5 concludes.

[1] In the case of Bos and Harrington Jr (2010), it is shown that a cartel amongst the largest firms is stable, although there is a set of stable coalitions which can face competition from the largest firm(s).

[2] In 2017, the European Commission ruled that Scania had broken EU antitrust rules, a decision which was later appealed by Scania. The appeal was dismissed by the General Court in 2022.

2.2 Literature review

2.2.1 Cartel stability

Internal stability The intuition behind the internal stability problems faced by cartels can be traced back as early as J. Bertrand (1883), who argued that a firm pricing above cost will incentivize its competitor to undercut him, thereby capturing the market. This insight led many to question the viability of price-fixing agreements. If each conspirator has an incentive to undercut the agreement, this would render cartels inherently unstable.

The standard framework to analyse this issue consists of a non-cooperative supergame, see for instance Friedman (1971) or Rotemberg and Saloner (1986). At each stage of the game, firms can either adhere to the cartel agreement or undercut their co-conspirators, yielding them unique monopoly profits. As price-fixing agreements are not court enforceable, a stable cartel needs to ensure that the expected returns from breaching the agreement are less than those resulting from adherence. The literature therefore proposes various internal enforcement mechanisms to prevent price-cutting, such as Nash reversion and price wars, which ensure that any gains from cheating are outweighed by the loss resulting from punishment.

Although the inner workings of a cartel are still somewhat of a black box, there is ample evidence which shows that cheating is an important concern and punishment mechanisms do not exist solely on paper. For instance, Porter (1983) and later Ellison (1994) investigated a US railroad cartel which regularly engaged in price wars, conforming to a model proposed by Green and Porter (1984). Another famous example is given by Bresnahan (1987), who examines price wars in the US automobile industry. The importance of price monitoring, which prevents mistaken inference on cheating, can also be deduced from various examples, where information exchanges were put in place specifically to avoid this situation.[3]

Other cases have shown that cheating is not only a prime concern, but sometimes a necessary evil which - to a certain degree - can be accommodated. In the lysine cartel, a manager of one of the colluding firms (Ajinomoto) claimed that cheating was frequent among its co-conspirators, but that "the range of cheating is not too big ... they kept their promise about 90 percent of the time, something like that"

[3]These include the sorbates cartel, the vitamins cartel and the auction house cartel between Sotheby's and Christie's. For a more elaborate discussion, see Harrington Jr (2006b).

(Connor, 2001). Additional examples, as well as a theoretical underpinning for this phenomenon, are provided by Bernheim and Madsen (2017), whose model of collusion introduces a floor price below which cheating is considered unacceptable, triggering punishment.[4]

External stability As a result of the internal stability problems faced by cartels, the literature has largely restricted its attention to all-inclusive cartels. The presence of outsiders is assumed to destabilize price-fixing agreements as these firms are not bound by any punishment mechanism and therefore free to undercut the cartel with impunity.

The destabilizing effect of outsiders is supported by the conduct cartels sometimes display towards non-colluding firms. As these firms are not bound by collusive agreements, cartels have employed alternative means to curtail outsiders. Connor (1998) mentions that the citric acid cartel (which did not include Chinese competitors) lobbied the office of the US trade representative to impose prohibitive tariffs on Chinese imports. Harrington Jr et al. (2018) discuss the different ways in which cartels attempt to handle the threat of non-cartel supply, with an empirical application to the German cement cartel. Other examples are given by Marshall et al. (2016) and Heeb et al. (2009), with the latter stating that once a cartel overcomes the internal stability issues, "it moves on to implement practices designed to diminish competition from existing and potential non-cartel rivals".[5] This issue is sometimes referred to as the cartel's external stability problem.

Nonetheless, actual cartel cases demonstrate that (at least when it comes to detected cartels) all-inclusivity is more of an exception than the rule.[6] For instance, Marshall et al. (2016) reviewed cartel cases brought before the EC between 2000 and 2005, showing that joint market shares of the colluding firms varied between a lower bound of 58% of the market and an upper bound of close to 100%. Theoretical contributions have established conditions for cartel stability in the case of incomplete cartels, examples of which include d'Aspremont et al. (1983), Donsimoni et al. (1986), Shaffer (1995) or Bos and Harrington Jr (2010). In general, it is agreed that while incomplete cartels can be stable, they allow outsiders to both increase their price and market share.

[4] These examples include the citric acid cartel and the sugar institute (Genesove and Mullin, 2001).
[5] These include the vitamins cartel and the EMCGP cartel.
[6] The implications of undetected cartels can be of importance if there are clear differences between those that are detected and those that remain hidden, and these differences are in turn identified as collusive markers. This issue is further discussed in section 2.4.

Empirical evidence of outsiders free riding in the presence of a cartel is provided by Bos, Letterie, et al. (2019) and Hüschelrath and Veith (2016). The former examine changes in company valuations after a cartel is detected under the hypothesis that cartels increase (and consequently detection decreases) the profitability of colluding firms. Interestingly, they find that detection not only hurts the stock price of colluding firms, but also those of outsiders, suggesting that the presence of the cartel yielded positive externalities for the latter. In a similar vein, Hüschelrath and Veith (2016) find that cartel breakdowns in the German cement industry resulted in lower prices for both the colluding firms and those that remained outside the agreement.

Market shares Inderst et al. (2014) refer to this effect, i.e. outsiders increasing their prices in the presence of a cartel, as the umbrella effect. For a more theoretical discussion, see appendix B.1.2, specifically proposition 2. While the umbrella effect with respect to price is well established, even sparking a debate on whether or not colluding firms should be held responsible for the increase in rivals' prices who were not part of the cartel, I focus on a second feature of outsider competition. As mentioned previously, outsiders are presumed to not only increase their prices under the umbrella of the cartel, but also their market share. Further theoretical contributions which support this hypothesis include Salant et al. (1983) and Deneckere and Davidson (1985).

An empirical example is provided by Igami and Sugaya (2021), who studied the vitamin C cartel in which Chinese producers made up a large competitive fringe. These firms were able to expand their market share at the expense of the participants, which is hypothesized to have contributed to the cartel's collapse. In the case of the citric acid cartel, Chinese competition resulted in the cartel's global market share decreasing from 70% to 52%. Barbezat (1996) examines French inter-war steel cartels, finding that their inability to stop non-members from undercutting the cartel resulted in a loss in market share. Further examples include the vitamin B1 and the methionine cartel (Harrington Jr, 2006b)

This phenomenon cannot be separated from cartels attempting to discipline non-collusive firms as discussed by Marshall et al. (2016). If outsiders simply increase their price in line with the cartel, there would be no real distinction between cartel participation and free riding. Should they increase their prices while simultaneously undercutting the cartel, this could become (from the cartel's perspective) a reason for concern. From the perspective of antitrust practitioners, however, it could open up interesting avenues to explore.

2.2.2 Prosecution and detection

Cartel detection When it comes to detecting infringements, competition authorities largely rely on three tools: (i) leniency, (ii) whistle-blowers and (iii) indirect (economic) evidence.[7] The latter can be used to raise red flags over certain industries or firms, prompting authorities to launch a deeper investigation, and can be subdivided into two types: structural and behavioural. Structural evidence attempts to identify industries which are at higher risk of collusion based on economic theory, thereby guiding competition authorities on how to allocate their efforts.[8] For a more in depth discussion, see Grout and Sonderegger (2007).

Behavioural evidence, as the name suggests, consists of behaviour which is likely to present itself in the presence of a cartel. Harrington Jr (2006a) discusses a number of behavioural markers which could signal collusion, such as higher prices coupled with reduced variation in prices across customers or a decrease in imports. With regards to market shares, it is mentioned that in the presence of an all-inclusive cartel market shares tend to be more stable compared to the competitive scenario, meaning stability over time could hint at collusion.

In the case of an incomplete cartel, it is acknowledged that a cartel's market share tends to decrease, resulting in the following extension: "There is a subset of firms for which each firm's share of total supply for that subset [...] is highly stable over time". Although implied, no explicit mention is made of a corollary to this marker, i.e. there is a subset of firms whose market share decreases while each firm's total share of supply for that subset is stable over time.

Moreover, economic literature on incomplete cartels suggests that these will consist of the largest firms in an industry. For a theoretical underpinning, prior reference was given to Donsimoni et al. (1986), Bos and Harrington Jr (2010) or Bos and Harrington Jr (2015), whereas empirical evidence includes Hay and Kelley (1974) and Asch and Seneca (1975). A possible marker could therefore be the presence of a group of large firms who suddenly lose market share at the expense of smaller or fringe competitors. This would be especially suspect when paired with an increase in prices across the industry, meaning market shares could be used as a refinement tool.

[7] The distinction between a whistle-blower and a leniency applicant is that the former group consists of (ex-)employees and related third parties, whereas a leniency applicant is the colluding entity itself, see Friederiszick, Maier-Rigaud, et al. (2007)

[8] For instance, markets characterized by a low number of firms are assumed to facilitate collusion, as it is both easier to come to an agreement and decreases the risk of price-cutting. Furthermore, and related to the previous discussion, a more transparent market is assumed to make collusive agreements more stable, as it allows firms to better monitor each other's prices and detect cheating.

If prices increase and fringe firms manage to obtain a larger share of the market simultaneously, this provides both a clearer signal that something might be amiss and a stronger case in potential litigation, as will be discussed in the next section.

Nonetheless, empirical research on the potential role of market shares in (behavioural) cartel detection has remained limited. One of the few contributions is provided by Geist and Blanckenburg (2011), who test the hypothesis that cartel market shares are more stable under collusion using data on ten cases. Looking for differences in the distribution of market share changes under the cartel compared to competition, they found that in only three out of ten cases the distribution differed significantly. In turn, this might cast doubt on the overall implementability of a screen based on market share stability.

Cartel prosecution While economists have devised a variety of methods to detect collusion, examples of which include Boswijk et al. (2019) Porter and Zona (1993), Crede (2019) and Abrantes-Metz et al. (2006), the role of economic evidence in cartel prosecution has remained limited. As mentioned in chapter 1, this is mainly due to the fact that cartel prosecution requires a higher standard of proof. In the case of detection, a marker of collusive behaviour can be useful as a starting point for further investigation, allowing for raids by antitrust authorities intended to obtain smoking-gun evidence. However, during prosecution, it needs to be demonstrated that - if entered as evidence - a collusive marker is the result of illicit agreements, requiring the exclusion of all other possible causes.

It is well understood that various suspicious actions, although perhaps useful in cartel detection, fall short as proof due to the fact that they cannot exclude competition. This issue is referred to as conscious parallelism or parallel conduct, essentially stating that firms simultaneously increasing prices or reducing output cannot be attributed to changes in conduct. If prices are strategic complements or outputs are strategic substitutes, this type of behaviour will present itself regardless of how firms compete. For a more in depth discussion, see Werden (2003). As a case in point, both outsiders and cartel members are assumed to increase their prices under collusion, although only the latter are behaving in a prohibited manner.

In order to overcome this issue, legal scholars have proposed the use of so-called *plus factors*, which refer to actions that are inconsistent with unilateral conduct, thereby suggesting concerted action, see Kovacic et al. (2011). As mentioned in the previous chapter, one example is the *action against self-interest*, which refers to actions that are contrary in a competitive scenario, but rational in the presence of

illicit agreements. An important precedent is given by *Matsushita*, where a US court argued that the provided evidence did not exclude permissible competition, and plaintiffs needed to present evidence which "excluded the possibility that the alleged conspirators acted independently".[9] This led experts to conclude that evidence of actions contrary to self-interest (in a competitive context) provided "precisely what is required to carry this burden".

In this chapter, I propose the use of market shares as economic evidence of an action against self-interest. As a specific application, I examine how market shares can be used to establish cartel participation. In this sense, I revisit the output test proposed by Blair and Romano (1989), who argued that if a cartel decreases output, outsiders are not bound by this agreement. Should the start of a cartel coincide with an increase in a firm's output - while the colluding firms see a decrease in output - this would suggest non-participation.

While parsimonious, there are some issues with this approach. First, as Bos (2009) notes, cartel formation could coincide with an expansion in cartel output given a positive shock to demand. In turn, this could allow for a colluding firm to easily pass the test proposed by Blair and Romano (1989). Second, Montero and Guzman (2010) demonstrated that output expanding collusion is a theoretical possibility given a large enough fringe, leading colluding firms to prioritize constraining fringe output over contracting their own output. Changing the focus to relative changes in demand, i.e. market shares, circumvents this issue. Although aggregate demand might increase, a larger share of this increase is still allocated to outsiders.

As an additional problem, there is a deeper methodological issue when considering industries with product differentiation. While a simple output test might be used in the case of homogenous products (Salant et al., 1983) or symmetric competition (Deneckere and Davidson, 1985), it is not excluded that the market share of a cartel member increases during collusion. For a more in depth discussion, see the theoretical framework in appendix B.1.2, proposition 3, which expands these theoretical contributions to accommodate product differentiation. Intuitively, once a cartel is formed, joint-profit maximization can result in the cartel redirecting demand towards members which face less elastic demand. Although the joint market share of the cartel decreases, an increase at the individual level cannot be excluded.

In this sense, should a firm accused of cartel participation point to an increase in market share as evidence to the contrary, this does not satisfy the required standard of proof. However, should a firm see a decrease in market share, this provides

[9] Masushita Elec. Indus. Co. v. Zenith Radio Corpl., 475 U.s. 574 (1986).

evidence of participation, as it would constitute an action against self-interest. Outsiders are incentivized to undercut the cartel and increase their market share, meaning the absence of price-cutting indicates cartel participation.

2.3 Empirical evidence

2.3.1 The data and the cartel

The previous section suggests that cartel formation allows non-colluding firms to expand their market share. In the current section, this hypothesis is tested using data on market shares in the European commercial vehicle market, where truck manufacturers colluded on the pricing of heavy and medium commercial vehicles. Throughout the rest of this chapter, both are simply referred to as commercial vehicles or CVs, distinguishing them from light commercial vehicles (LCVs).

The cartel Between 1997 and 2011, the six largest truck manufacturers active on the European market - Daimler, MAN, Volvo/Renault, Iveco, DAF and Scania - had been part of a cartel. During this period, they agreed to raise and align the prices of medium (6-16 tons) and heavy CVs (over 16 tons) across the single market. The end of the cartel resulted from German manufacturer MAN blowing the whistle under the EC's leniency notice.

In the CV market, prices are based on gross price lists set by each company's headquarters for finished vehicles, i.e. the factory gate price, after which both local distributors and dealerships add a markup to the final consumer price. During the cartel period, the cartel members had conspired to increase their factory gate prices across the EEA. From the introduction of the Euro currency onward, this process was facilitated by the introduction of EEA-wide gross price lists. After the introduction of the Euro, the cartel members started to systematically exchange information via their German subsidiaries and reduce discounts. They shared both information on current prices and planned price increases during regular meetings or via email. For a more elaborate discussion on the cartel, see Chapter 1.

The Data The main source of data used in this analysis are the monthly vehicle registrations by type and manufacturer on the EEA market. This data is publicly available from 2001 onwards and provided by the European Automobile Manufacturers Association (ACEA). The sample used in this chapter runs from 2001 until

Table 2.1: Summary statistics.
Source: ACEA.

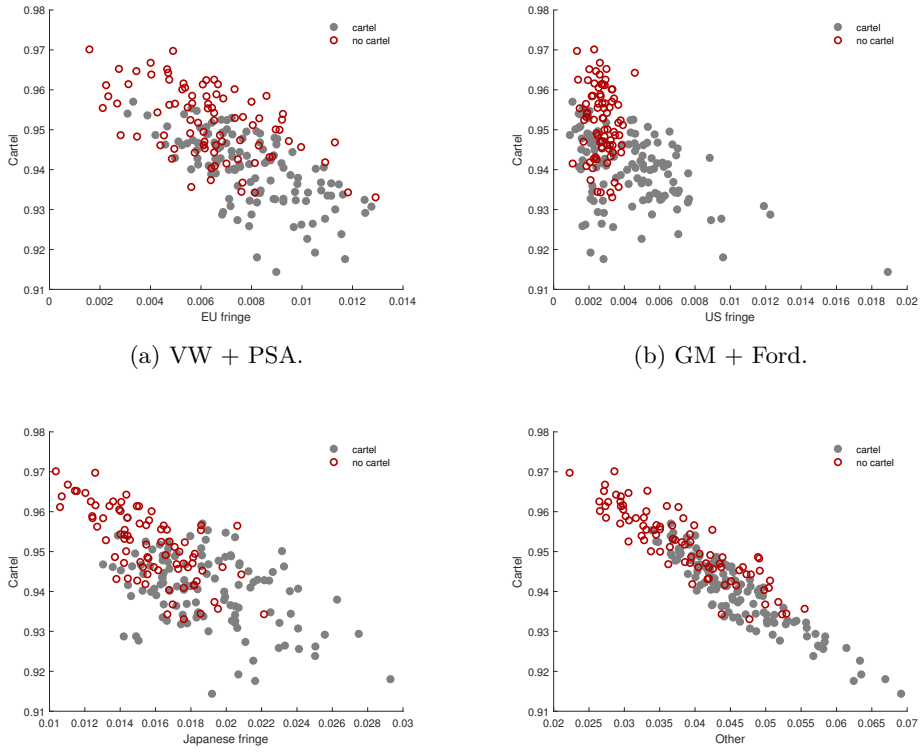
	Firm		Obs.	Mean	Std. dev.	Min.	Max.
Cartel	DAF		204	3388	991	1545	9973
	MAN		204	4094	1055	1875	10241
	Scania		204	2854	801	1157	6293
	Volvo		204	3251	900	1097	7142
	Renault		204	2646	789	906	5585
	Daimler		204	6288	1374	3532	14347
	Iveco		204	4037	1111	2094	7628
Outsiders	Japanese fringe	*Honda, Suzuki, Toyota, Nissan, Mazda, Mitsubishi*	204	492	145	270	1193
	VW		204	169	60	19	326
	PSA		204	30	20	1	126
	GM		204	35	39	0	264
	Ford		204	67	31	11	214
	Rest	*Daewoo, Hyundai,...*	204	732	199	295	1438

2017 and consists of medium and heavy commercial vehicle registrations on the European market. The cut-off date is given by the fact that after 2017 registrations of trucks and buses are no longer reported separately, which complicates any possible comparisons with the pre-2017 sample.

Table 2.1 provides summary information on the number of registrations for the individual firms, which are categorized as either (former) cartel members or outsiders. Consistent with the theoretical predictions, the cartel consists of the largest firms on the market. Moreover, the EC's investigation revealed no evidence of the cartel taking action to curtail the noncartel firms. When it comes to these outsiders, the ACEA reported registrations for a large number of Japanese firms, which are grouped together. This is due to how the data was reported. In some years, Japanese registrations were disaggregated across certain individual firms, whereas in other years certain firms were omitted.[10] Similarly, registrations for some very small firms (in terms of market share) were reported in certain years, but not in others. These firms were grouped together in a 'other' category. The fringe is further made up of US (GM and Ford) and European outsiders (PSA and VW).

Figure 2.1 plots the market share of different producers on the European CV market relative to the cartel's market share. Market shares are defined as a firm's percentage of total registrations for a given month, which is assumed to equal the

[10]For instance, one year might report the registrations for Honda, Toyota and Nissan, as well as the total of Japanese registrations, whereas the subsequent year would report Honda, Toyota, the Japanese total but not Nissan's individual registrations.



(a) VW + PSA.

(b) GM + Ford.

(c) Japan.

(d) Other (Korean, Chinese, etc...).

Figure 2.1: Scatterplots of monthly EEA market shares, CV (2001-2017).
Source: Own calculations based on ACEA data.

number of sales. Each observation reports the monthly market share of outsider firms, which are bundled geographically, relative to the joint market share of firms convicted of colluding. I distinguish between European (2.1a), US (2.1b), Japanese (2.1c) and other (2.1d) outsiders. Observations during the collusive period (2001-2010) are indicated by a grey circle, whereas post-cartel observations are red (2011-2017).

Indeed, it not only seems that outsiders were able to maintain a larger market share during the collusive period, but that this result is fairly robust when the outsider firms are disaggregated at the geographic level. The main question now becomes: is this pattern the result of cartel activity? In order to answer this question, it is necessary to consider if there exists firm-level heterogeneity - distinguishing between outsiders and cartel members - which might account for this change and is unrelated to competitive conduct.

2.3.2 Empirical strategy

I take a two-step approach in order to illustrate that the end of the cartel caused a decrease in outsider market share, which in turn supports the hypothesis that outsiders are able to maintain a larger market share in the presence of a cartel.

As a first step, I demonstrate that the movement in market shares on the CV market is consistent with outsider firms undercutting the cartel by searching for changes in the covariate structure of a simple regression model. This type of approach has recently been employed in the detection of collusive conduct, see for instance Boswijk et al. (2019) or Crede (2019). The advantage of the proposed regression framework as opposed to simply looking at and comparing market shares is that it (i) allows for statistical methods to detect changes in competitive conduct and (ii) provides a formal framework in which to compare changes in market shares across different sectors.

In a second step, I attempt to establish causality using a control group approach, in order to demonstrate that firm-level heterogeneity is not a satisfactory explanation for these changes.

The model

Let the total number of registrations on the CV market, denoted q, be divided among outsiders and the cartel, which are indicated by the subscripts o and c respectively,

Table 2.2: Regression estimates.

coefficients	(1)	(2)	(3)	(4)
β_0	0.53	1.31***	0.98***	0.91***
	(0.54)	(0.41)	(0.02)	(0.02)
β_1	0.67***	0.60***	0.92***	0.67***
	(0.05)	(0.05)	(0.06)	(0.08)
β_2	-	-0.26***		-0.11***
		(0.02)	-	(0.03)
R^2	0.36	0.63	-	-
Obs.	204	204	204	204

$^{***}p < 0.01$, standard errors in parentheses.

such that $q_o + q_c = q$. Note that

$$\ln q_{ot} = \ln q_{ct} - \ln q_{ct} + \ln q_{ot} \tag{2.1}$$

$$= \ln q_{ct} + \ln \left(\frac{s_{ot}}{s_{ct}} \right), \tag{2.2}$$

with $s_{it} = \frac{q_{it}}{q_t}$. Based on (2.2), the following linear model is considered as a starting point to detect the presence (or absence) of a change in outsider market shares relative to the cartel

$$\ln q_{ot} = \beta_0 + \beta_1 \ln q_{ct} + \beta_2 \delta_t + \epsilon_t, \tag{2.3}$$

with

$$\delta_t = \begin{cases} 0 & \text{if } t \leq k, \\ 1 & \text{if } t > k, \end{cases} \tag{2.4}$$

and k denoting the end of the cartel. Inclusion of this dummy is motivated by the fact that, under the hypothesis that the end of the cartel resulted in a sudden and persistent decrease in outsider market share, this would introduce a break in the covariate structure, as the intercept would predictably decrease.

Let $k = 120$, which is the official end date of the cartel as given by the EC. Estimation results are displayed in table 2.2, once excluding (1) and once including (2) δ_t. It can be seen that the model is not sophisticated enough to fully track the data as fluctuations in market shares unrelated to cartel activity are not taken into account. Given that $s_{ot} < s_{ct}$ for each t, equation (2.2) suggests that the intercept should be negative. In both specifications this is not the case due to the fact that the estimate on β_1 is less than one.

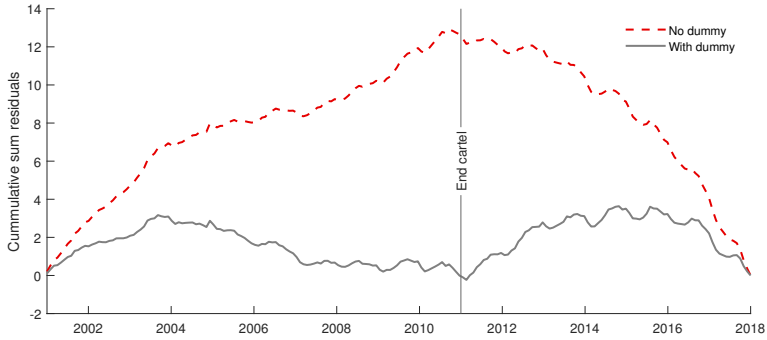


Figure 2.2: Cummulative sum of OLS residuals, a comparison.

Nonetheless, there are some interesting takeaways. The estimate on β_2 is negative - as would be expected if the cartel resulted in a loss in outsider market share - and statistically significant at the 1% level. In addition to this, inclusion of the dummy significantly increases the model fit as R-squared nearly doubles. The most interesting find is shown in figure 2.2, which depicts the cumulative sum of residuals over time for both specification (1) and (2).

OLS estimation omitting competitive conduct (in this case represented by δ_t) introduces endogeneity into the model under the current hypothesis. If outsiders are able to obtain a larger share of the market when the cartel is active, β_0 is expected to be on average larger during the collusive period relative to the non-collusive period. In turn, this introduces serial correlation in the errors.[11] If there is a switch from collusion to competition during the sample period at time $t = k$, it is likely that

$$\widehat{\ln q_{ot}}(\ln q_{ct}) \begin{cases} < \ln q_{ot} & \text{if } t \leq k, \\ > \ln q_{ot} & \text{if } t > k, \end{cases}$$

meaning the errors tend to be positive when $t \leq k$ and negative when $t > k$. Indeed, looking at figure 2.2 it can be seen that the cumulative sum of residuals increases until the end of the cartel. As OLS errors sum to zero by construction, the sum then (necessarily) decreases to zero once $t > k$. Including the dummy eliminates a large fraction of the auto-correlation.

Equation (2.3) can be expanded to better account for changes in market shares

[11] The Breusch-Godfrey test overwhelmingly rejected the null hypothesis of no serial correlation in the residuals.

over time. For notational simplicity, define $r_t = \ln\left(\frac{s_{ot}}{s_{ct}}\right)$ and consider the following regression

$$\ln q_{ot} = \beta_0 \ln q_{ct} + \beta_1 \hat{r}_t + \beta_2 \delta_t + \epsilon_t \tag{2.5}$$

As the residuals are correlated over time, the serial correlation is modelled parametrically and r_t is approximated using an autoregressive[12] model such that

$$\hat{r}_t = \alpha_0 + \sum_{i=1}^{2} \alpha_i r_{t-i}. \tag{2.6}$$

Employing an AR(2) model does not change the setup, as it makes predictions based on past information and therefore requires that there are no dramatic changes in the underlying fundamentals. Estimation results are again reported in table 2.2, without (3) and with (4) dummy variable. The coefficient estimates are closer to their theoretical values under a correctly specified model. Nonetheless, the estimate on β_2 is again negative and statistically significant.

Detecting collusion A regression approach allows for the use of time series methodologies which search for persistent changes in a model, see Casini and Perron (2018). For instance, consider equation (2.3), in which δ_t is governed by a variable $k \in [1, T]$, with T being the length of the sample. Let the vector of OLS estimates be a function of k, meaning the corresponding sum of squared residuals, denoted $SSR(k)$, differs conditional on $k \in [1, T]$. The estimated break date k^* then corresponds to

$$k^* = \arg\min_{[1,T]} \Big\{ SSR(k) \Big\}. \tag{2.7}$$

Such a break can be found by running a search algorithm for the optimal partition over the length of the sample. In turn, it is then possible to employ statistical tests to assess whether this break is statistically significant against the null-hypothesis of no break, i.e. $H_0 : \beta_2 = 0$. If it is found that there is a statistically significant break around the end of the cartel, this supports the hypothesis that outsiders were able to maintain a larger market share by undercutting the collusive agreement.

As an illustration, I employ a Wald supremum test, which detects a structural change in time series and allows for serial correlation in the errors. Consider the

[12] The number of lags included was motivated by minimizing the AIC and BIC. The time series on r did not contain a unit root.

following model

$$\ln q_{ot} = \beta_0 + \beta_1 \ln q_{ct} + \delta_t(\beta_2 + \beta_3 \ln q_{ct}) + \epsilon_t, \tag{2.8}$$

for which it is assumed a single unknown break exists, at which point the dummy δ_t is switched on. This is analogous to subdividing the sample and re-estimating the coefficients for each sub-sample.

The optimal break date maximizes a test statistic against the alternative hypothesis that there is no break present, i.e. $H_0 : \beta_2 = \beta_3 = 0$, see for instance Quandt (1960) or Andrews (1993). In the case of a Wald supremum test, the break date k^* maximizes the Wald test statistic $W(k)$ over the admissible sample, which lies between a lower bound t_l and an upper bound t_u.

$$k^* = \sup_{t \in [t_l, t_u]} \Big\{ W(k) \Big\}. \tag{2.9}$$

I refer to an admissible sample, as it is necessary to introduce a cut-off, demarcating the minimum sub-sample size over which the coefficients are estimated. As a rule of thumb, this is 15% at either end of the sample. Reducing the size of this cut-off to 5% does not change the result. Boswijk et al. (2019) notes that this type of tests is sensitive to finite sample size. As a result, standard errors are obtained using a standard nonparametric bootstrap (1000 iterations).

Table 2.3: Wald test for structural break

Test	Statistic	p-value
Swald	151.0568	0.0000
Full sample:	1-204	
Trimmed sample:	32-174	
Estimated break:	Oct. 2010 (obs .118)	

Table 2.3 presents the estimated break date, overwhelmingly rejecting the null hypothesis of no break in the trend parameter. The estimated break point k^* which maximizes W is the 118th observation, which corresponds to October 2010. This is interesting given that MAN blew the whistle on the truck cartel in the previous month, followed by raids at the various offices two months later. Although speculative, this could suggest that the collusive agreement was becoming less stable, resulting in a race-to-the-courthouse effect as discussed by Harrington Jr (2008). A similar and statistically significant break date (obs. 116) can be found when using

specification (2.5), in which the serial correlation is modelled parametrically.

Outsider-specific heterogeneity

The previous section demonstrates that there was a persistent decrease in outsider market share which coincided with the end of the cartel. It should be noted that there are some clear distinctions between the cartel members and the outsiders, as the former (i) supply a much larger quantity of trucks (see table 2.1) and (ii) possess significant production facilities in Europe, whereas the outsider firms generally do not.[13] Possible sources of heterogeneity contributing to the previous finds could therefore be region-specific cost shocks which affect the outsiders disproportionately, increased tariffs, trade barriers and shipping costs, or EU regulation excluding some imported models not intended to be sold exclusively on the European market (although in the case of emissions, other countries have largely patterned their emission standards on European regulations).

If any such changes resulted in outsiders seeing a decrease in market share at the time when the cartel ended, this could wrongfully be attributed to the cartel. One potential approach to address firm-level heterogeneity is a framework as employed by Card and Krueger (2000), in which a treatment group is compared with a control group subject to similar trends but not the same treatment. I test the validity of the hypothesis using a comparative approach by exploiting the fact that firms which are active on the CV market are also active on the bus market. In this sense, the end of the cartel is considered a 'treatment' to which the bus market was not subject.[14]

The bus market Buses and trucks are generally produced by the same vertically integrated manufacturers and inputs used in production can be either shared or manufactured in the same plants, e.g. chassis, gearboxes, transmissions, axles and engines. Final assembly can take place in the same location, although this is

[13] Interactive map Automobile assembly and production plants in Europe

[14] It should be noted that such an approach requires that assignment of the treatment is exogenous conditional on the outcome of interest (M. Bertrand et al., 2004 or Besley and Case, 2000). The treatment consists of the cartel's dissolution, which was triggered by MAN blowing the whistle. Conventional economic wisdom suggests this occurs when the discounted profit from collusion under a certain probability of detection no longer exceeds the returns from applying for leniency and a return to competition. This points to one of two effects being at play: (i) the chance of detection increased or (ii) the cartel became less profitable (Harrington Jr, 2008). In the first case, this would suggest that the cartel's dissolution is exogenous to any outsider-specific changes, as detection is the responsibility of competition authorities. In the second case, it runs counter to what is observed, as firm-specific shocks which reduce the outsiders' ability to undercut the cartel would hint at increased cartel profitability.

Table 2.4: Average market shares European market, 2001-2017.
Source: Own calculations based on ACEA data.

Firm	**Market share (%)**		Firm	**Market share (%)**	
	Truck	Bus		Truck	Bus
DAF	12.0	1.6	Japan	1.7	0.3
MAN	14.6	9.0	GM	0.1	0.3
Scania	10.1	5.0	Ford	0.3	5.7
Volvo	11.5	7.7	VW	0.6	1.3
Renault	9.4	2.6	PSA	0.1	0.4
Daimler	22.5	30.0	Others*	2.6	18.1
Iveco	14.3	17.9	-		
Total	94.4	73.8	Total	5.4	26.1

* Registrations from smaller suppliers are grouped together as 'others' in the ACEA's registrations.

not necessarily the case. Both buses and CVs were subject to the same emission regulations, as they are considered a distinct category (heavy-duty diesel engines). Lastly, it seems unlikely that increased duties and tariffs or region-specific cost shocks would impact a firm's bus production capabilities differently compared to CV production.

Buses (officially buses and coaches over 3.5 ton), although essentially commercial vehicles intended for passenger transport, are considered distinct from 'commercial vehicles' in the ACEA registrations, which refers exclusively to trucks. Table 2.4 depicts the average market share of different manufacturers on the EEA truck and bus market. Indeed, the firms active on both markets are largely the same, although the firms which colluded on the truck market possessed a smaller joint market share of 73.8% on the bus market, compared to 94.4% on the truck market.

Figure 2.3 suggest that fluctuations in demand for CVs (2.3a) and buses (2.3b) are comparable. One interesting feature to support his claim is that both experienced similar sharp upticks around 2006 and 2013. The only difference seems to be the cyclical component, where the demand for CVs experienced a much larger decrease during the Great Recession years.

Synthetic controls Table 2.4 shows that the comparison is not perfect as a firm's position in the market can differ by product category (e.g. Ford has a much larger market share on the bus market in comparison to the truck market). It could therefore be argued that any firm-specific effects which lowered market shares for

the outsiders post-treatment on the truck market could be absent on the bus market if the driving firms behind this trend are under-represented.

For instance, if a cartel member which possesses a sizeable market share on the truck market sees its market share halved due to an event unrelated to collusion, this could have significant impact on the cartel's joint market share. However, if this firm's market share on the bus market is negligible, the impact of the event on the cartel's bus market share would be negligible as well, even if it constitutes a halving of the firm's share on that market. This could in turn falsely suggest that collusion might lie at the heart of this evolution. One potential way to circumvent this issue is a synthetic control approach as pioneered by Abadie and Gardeazabal (2003). Such an approach is feasible when a treatment affects a small number of large units, which describes the current case.

A synthetic control approach aims to make the control and treatment group more comparable, by creating a composite control group which better reflects the characteristics of the treatment group. As an example, Abadie and Gardeazabal (2003) use this type of approach the estimate the effects of terrorism in Basque Country. As other Spanish regions both share certain similarities and exhibit important differences with Basque Country, they create a synthetic control region using a combination of control regions, which closely mimics the pre-treatment characteristics of the treated unit (Basque Country).

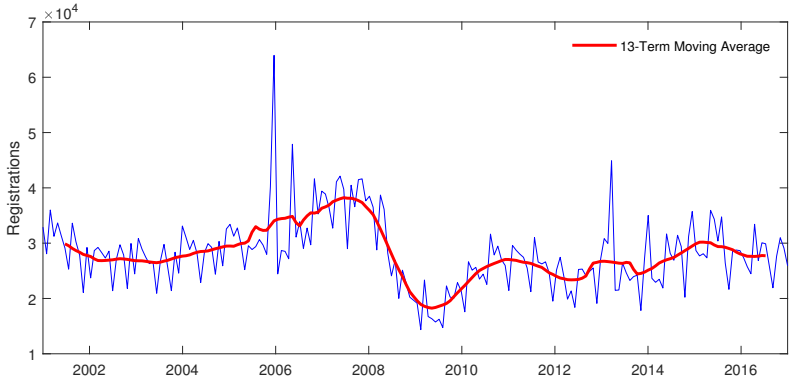
Overall, the selection of comparison units in a synthetic control approach is based on a data driven procedure, see for instance Abadie (2021). In the current application, a more straightforward approach presents itself as it is possible to assign a weight to the output of each firm on the bus market, which minimizes the distance between the pre-treatment (firm-level) output vectors on the bus and CV market. This approach is intuitively justified, as the resulting vector of weights is supposed to reflect the importance of each variable when comparing treated and control units.

Let the subscripts c and b denote CV and bus registrations respectively. Each firm $i = 1, 2, ..., n$ is assigned a weight w_i such that

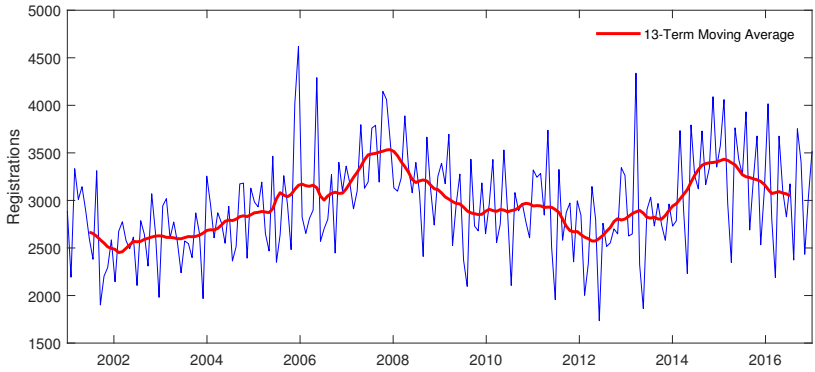
$$w_i = \arg\min_{x \in \mathbb{R}^+} \|\mathbf{q}_{ic} - x\mathbf{q}_{ib}\|, \tag{2.10}$$

with $\mathbf{q}_{ij}$ denoting a $k \times 1$ vector of firm i's output on market j before the end of the cartel at time k. Let $\mathbf{Q}_{ij}$ be The $T \times 1$ vector of total registrations, with T being the length of the sample. The synthetic CV market is then given by the following

Figure 2.3: Comparison of trends.
Source: ACEA.



(a) CV monthly registrations, total.



(b) Bus + coach monthly registrations, total.

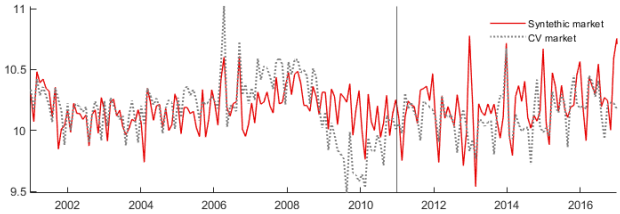


Figure 2.4: Synthetic CV market, $\ln(q_o + q_c)$.

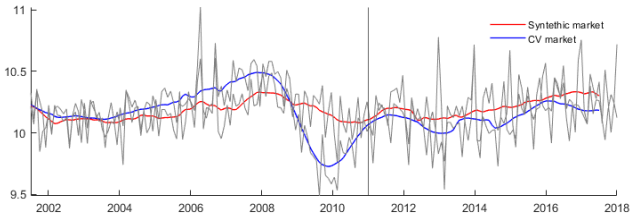


Figure 2.5: Trend-cycle component, MA(12).

$T \times n$ matrix

$$\hat{\mathbf{Q}}_c = [\, w_1 \mathbf{Q}_{1b} \quad ... \quad w_n \mathbf{Q}_{nb} \,]. \tag{2.11}$$

On figure 2.4 it can be seen that the synthetic market adequately tracks the actual CV market until 2008. However, it can also be seen that the bus market is much less impacted by the recession in comparison.[15] This could pose an issue if the observed pattern is the result of cartel firms recovering faster from the recession in comparison to outsiders and this evolution is not present on the bus market.

Results I estimate (2.3) for two control groups - buses and synthetic CVs - to see if there are any similarities present. The regression results are reported in table 2.5. For each control group, q_c is the sum of registrations for firms which were part of the cartel on the truck market. In the case of both buses and synthetic CVs, the estimate on β_2 is positive, suggesting that outsider market share actually increased on average after the treatment. This speaks against the relative decrease

[15] It cannot be excluded that this difference was itself caused by cartel activity. Various contributions including Athey et al. (2004), Harrington Jr (2004) and Abrantes-Metz et al. (2006) argue that collusive conduct can increase price rigidity for a variety of reasons, whereas Rotemberg and Saloner (1986) argue that under imperfect monitoring cartel pricing can be countercyclical, which might explain a larger decrease in the demand for trucks relative to buses. This is also supported by the fact that during the recession outsiders experienced a sharp increase in their market share at the expense of the cartel members.

Table 2.5: Regression estimates.

	synthetic CV	buses
Coefficient		
β_0	-0.92	-0.22
	(0.82)	(0.61)
β_1	0.78***	0.89***
	(0.08)	(0.08)
β_2	0.06*	0.10***
	(0.03)	(0.03)
R^2	0.36	0.36
Obs.	204	204

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, standard errors in parentheses.

in fringe output in the truck market post-cartel being due to explanations unrelated to collusion.

Under the assumption that trends in the control group (busses and syntethic CVs) are similar to those in the treatment group (CVs) and variations in outsider market shares on the bus market are a reflection of changes in market share due to firm-level heterogeneities, the impact of the cartel's end on outsider market shares is quite sizeable. Using a difference-in-differences approach and comparing the model including auto-regressive terms (2.5) with the synthetic control group suggests that outsider market shares are on average 17% lower once the cartel ended. In other words, if we interpret this as the treatment effect, the presence of the cartel allowed outsiders to maintain a joint market share under the collusive umbrella which was on average 17% higher than their market share would have been in the competitive counterfactual.

As an important caveat, it should be mentioned that such an interpretation suffers from (atleast) one important drawback, as it assumes that changes in a firm's market share are independent of that firm's market position. Clearly, this is quite a stringent assumption. For instance, a more dominant position on the market suggests a higher degree of market power, which could be due to a variety of reasons. A firm's demand on one segment might be less elastic compared to another segment on which it has a less dominant position, be it due to better product quality, less efficient competitors, better brand reputation, etc. That being said, the sign on the end-of-cartel dummy being different for the truck sample and the two control groups does provide strong evidence that cartel activity lies at least partly at the root of

this difference, especially when paired with the fact that the Wald test suggests a structural break around the time of the cartel's end.

2.4 Practical implications

The previous findings support the claim that outsider firms are able to expand their market share under the umbrella of a cartel. As mentioned before, this finding might lend itself to certain applications. The present section focuses on one possible application as it revisits the output test by Blair and Romano (1989) and demonstrates how market shares can be used as proof of participation in a price-fixing conspiracy. Similarly to chapter 1, I consider the case of truck manufacturer Scania, which denied participation in a cartel.

2.4.1 The Output Test

Blair and Romano (1989) discuss a fictional cartel case set in the Pittsburgh cast iron widget industry, consisting of six firms producing homogeneous goods, in order to highlight the potential of output as an indicator of cartel participation. In 1987, customers started to notice irregularities, which led them to file an antitrust suit against all six producers. One of these, American Cast Iron Widget (ACIW), maintained its innocence. Although it did not deny the existence of a cartel, it insisted that it was not part of the infringement.

In order to present proof of non-participation, Blair and Romano (1989) suggest the use of output as a collusive marker. The theoretical underpinning of their approach is based on the fact that products are assumed homogenous and in Bertrand competition price equals marginal cost. If an incomplete cartel is formed, participants will maximize profits on the residual demand curve resulting from other producers pricing at marginal cost, equating residual marginal revenue to marginal cost. This results in a decreased joint output for the colluding firms and an increase in output for any outsiders. As a result, should a firm see a decrease in its output during the collusive period, this presents evidence against the hypothesis that it operated as a strategic outsider.[16]

[16]The authors acknowledge that although cartel output is assumed to contract, individual cartel members might see an increase. Nonetheless, they defend their approach as it will never wrongfully identify a non-participant as a participant, which under the standard legal paradigm is the error which should be minimized.

2.4.2 An application: Scania

In a similar - but factual - scenario, one of the defendants in the truck cartel case maintained its innocence: Swedish manufacturer Scania. Although the other defendants agreed to settle in exchange for a reduction in fines, admitting to the charges, Scania resisted settlement, claiming that no explicit agreements were made during the various information exchanges and that Scania was never part of any arrangement to increase prices or coordinate on any other parameter.[17]

Nonetheless, the EC considered the documentary evidence sufficient, finding Scania guilty of an infringement of article 101 TFEU and imposing an €880 million fine, a decision which Scania appealed. As a robustness check of this decision, I employ an output test in order to determine whether or not Scania participated in the infringement. However, as opposed to Blair and Romano (1989), I shift attention away from quantities towards market shares.

Table 2.6: Wald test for structural break, regression (2.12).

Test	Statistic	p-value
Swald	211.86	0.00
Full sample:	1-204	
Trimmed sample:	32-174	
Estimated break:	Oct. 2010 (obs .118)	

Figure 2.6 depicts Scania's quarterly market share on the heavy CV market and its (deflated) revenue per heavy truck sold, which is used as a proxy for prices.[18] Both are smoothed using a MA4 seasonal adjustment. As can be seen, the formation of the cartel did not result in any notable increase in market share. In fact, Scania's share starts to decrease around 2001, which coincides with the introduction of the Euro currency. It was around this time that the cartel started to systematically exchange pan-European price lists with the intent of harmonizing prices across markets. It can also be seen that the measure of Scania's prices starts to increase at this point. Equally interesting is the fact that after the dissolution of the cartel, Scania's market share increased over time, which runs counter to what would be expected in the case of an outsider undercutting the agreement.

Similar to earlier specifications, changes in market share are examined using the

[17] CASE AT.39824 -Trucks; Commission Decision of 27.9.2017, pp. 61.

[18] As opposed to other manufacturers, Scania solely produced heavy trucks. Revenue is deflated using the EU28 industrial PPI.

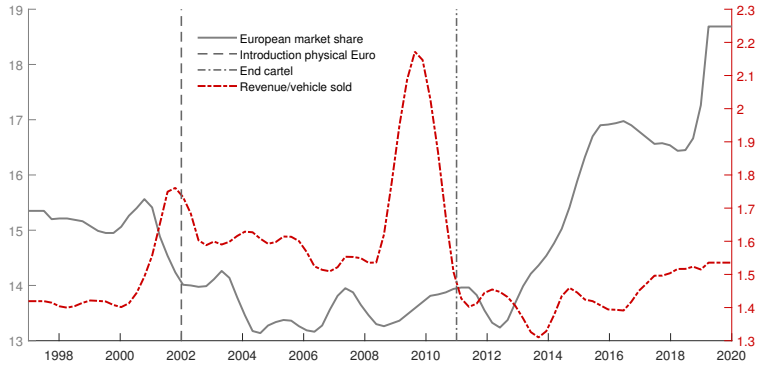


Figure 2.6: Scania market shares and revenue/vehicle sold in million SEK.
Source: Scania's quarterly reports.

following regression

$$\ln q_{ot} = \beta_0 + \beta_1 \ln q_{st} + \epsilon_t, \tag{2.12}$$

with q_{st} denoting Scania's monthly CV registrations. Using the Wald test for a single structural break yields an identical breakpoint to the one obtained in section 2.3.2, see table 2.6. When re-estimating (2.12) but replacing Scania's registrations with the total registrations of all defendants expect for Scania, such that

$$\ln q_{ot} = \beta_0 + \beta_1 \ln(q_{ct} - q_{st}) + \epsilon_t, \tag{2.13}$$

the break date remains the same, see table 2.7, thereby rebutting the argument that the break was solely caused by Scania.

Table 2.7: Wald test for structural break, regression (2.13).

Test	Statistic	p-value
Swald	136.35	0.00
Full sample:	1-204	
Trimmed sample:	32-174	
Estimated break:	Oct. 2010 (obs .118)	

In light of the previously obtained results, this suggests that Scania did participate in the cartel, thereby supporting the ECs decision. Moreover, the evidence could be considered stronger compared to Blair and Romano (1989). An increase in

market share does not necessarily indicate non-participation. Although the cartel's market share is hypothesized to decrease, this does not need to be the case for each individual cartel member. Consequently, output and market share expansion do not provide evidence against collusion. On the other hand, market share contraction is inconsistent with Scania undercutting the cartel, thereby providing proof against non-participation.

As mentioned before, there are clear limits to using market shares in the detection of non-participation at the individual level, meaning the use of such an approach should be done on an ad-hoc basis. In the case of Scania, market shares exhibited a pattern which was inconsistent with that of an outsider. To solidify the causal link between market shares and collusion, a Wald test was employed. A Wald test is only assumed to identify cartel end dates in an aggregate setting, but not necessarily at the individual level. If market shares shift within the cartel itself due to any number of reasons, a Wald test at the individual level might yield a different break date. As a further illustration, similar break dates to Scania were obtained for Daimler (116), Volvo (118), MAN (116) and to a lesser degree DAF (106), but not in the case of Iveco (96) and Renault (142).

Survivorship bias As a final caveat it should be noted that, due to their secret nature, it is unknown how many cartels are active at a given time and - more importantly - what distinguishes detected from undetected cartels. Consequently, any method which claims to play a role in detection needs to consider that whatever identifying aspect it points out could also be a contributing factor to why certain cartels were detected in the first place. If so, this means that such methodologies would have limited applicability.

As outsiders undercutting a cartel is assumed to be detrimental to its stability, it could be argued that non-detected cartels are the ones that have found a way to circumvent this issue, introducing survivorship bias.[19] While this type of bias can not be excluded, it should first be noted that the truck cartel was active for approximately thirteen years although it was not all-inclusive, with the evidence pointing to outsiders maintaining a larger market share due to restricted competition over the entire collusive period. Second, the previously discussed approach could

[19]The canonical example of survivorship bias is given by Wald (1980), who analyzed how to minimize US bomber losses in WW2 by looking at damage to returned aircraft. Returned planes showed extensive damage to the wings and tails, which could lead to the (erroneous) conclusion that these areas needed to be reinforced. This line of reasoning overlooks the fact that the returned (or surviving) planes were the ones who did not suffer fatal damage. Ignoring data on non-surviving places would therefore have lead to faulty conclusions.

still play a role when it comes to post-cartel litigation, as it both serves as evidence of cartel participation and provides evidence against parallel conduct.

2.5 Conclusion

The previous findings support the theoretical literature with regards to incomplete cartels. As predicted, a return to competitive conduct results in a decrease in the joint outsider market share, suggesting that the breakdown of collusive agreements eliminated opportunities to undercut the cartel. As an empirical application, changes in market shares were used to establish cartel participation. Alternatively, market shares could play a role in the discovery of cartels, especially in industries consisting of a few large firms and a large fringe, which are also assumed to be the type of industries susceptible to cartel formation. A sudden increase in the joint market share of the fringe, especially when paired with other suspicious changes on the market, could raise a red flag for antitrust authorities.

Bibliography

Abadie, Alberto (2021). "Using synthetic controls: Feasibility, data requirements, and methodological aspects". In: *Journal of Economic Literature* 59.2, pp. 391–425.

Abadie, Alberto and Javier Gardeazabal (2003). "The economic costs of conflict: A case study of the Basque Country". In: *American economic review* 93.1, pp. 113–132.

Abrantes-Metz, Rosa M, Luke M Froeb, John Geweke, and Christopher T Taylor (2006). "A variance screen for collusion". In: *International Journal of Industrial Organization* 24.3, pp. 467–486.

Amir, Rabah and Isabel Grilo (2003). "On strategic complementarity conditions in Bertrand oligopoly". In: *Economic Theory* 22, pp. 227–232.

Andrews, Donald WK (1993). "Tests for parameter instability and structural change with unknown change point". In: *Econometrica: Journal of the Econometric Society*, pp. 821–856.

Asch, Peter and Joseph J Seneca (1975). "Characteristics of collusive firms". In: *The Journal of Industrial Economics*, pp. 223–237.

Athey, Susan, Kyle Bagwell, and Chris Sanchirico (2004). "Collusion and price rigidity". In: *The Review of Economic Studies* 71.2, pp. 317–349.

Barbezat, Daniel (1996). "The Comptoir Sidérurgique de France, 1930–1939". In: *Business History Review* 70.4, pp. 517–540.

Bernheim, B Douglas and Erik Madsen (2017). "Price cutting and business stealing in imperfect cartels". In: *American Economic Review* 107.2, pp. 387–424.

Bernstein, Fernando and Awi Federgruen (2004). "Comparative statics, strategic complements and substitutes in oligopolies". In: *Journal of Mathematical Economics* 40.6, pp. 713–746.

Bertrand, Joseph (1883). "Book review of theorie mathematique de la richesse social and of recherches sur les principes mathematiques de la theorie des richesses". In: *Journal des savants*.

Bertrand, Marianne, Esther Duflo, and Sendhil Mullainathan (2004). "How much should we trust differences-in-differences estimates?" In: *The Quarterly journal of economics* 119.1, pp. 249–275.

Besley, Timothy and Anne Case (2000). "Unnatural experiments? Estimating the incidence of endogenous policies". In: *The Economic Journal* 110.467, pp. 672–694.

Blair, Roger D and Richard E Romano (1989). "Proof of nonparticipation in a price fixing conspiracy". In: *Review of Industrial Organization* 4.1, pp. 101–117.

Bos, Iwan (2009). "Incomplete Cartels and Antitrust Policy". PhD thesis. PhD thesis, Tinbergen Institute.

Bos, Iwan and Joseph E Harrington Jr (2010). "Endogenous cartel formation with heterogeneous firms". In: *The RAND Journal of Economics* 41.1, pp. 92–117.

— (2015). "Competition policy and cartel size". In: *International Economic Review* 56.1.

Bos, Iwan, Wilko Letterie, and Nina Scherl (2019). "Industry impact of cartels: Evidence from the stock market". In: *Journal of Competition Law & Economics* 15.2-3, pp. 358–379.

Boswijk, H Peter, Maurice JG Bun, and Maarten Pieter Schinkel (2019). "Cartel dating". In: *Journal of Applied Econometrics* 34.1, pp. 26–42.

Bresnahan, Timothy F (1987). "Competition and collusion in the American automobile industry: The 1955 price war". In: *The Journal of Industrial Economics*, pp. 457–482.

Bulow, Jeremy I, John D Geanakoplos, and Paul D Klemperer (1985). "Multimarket oligopoly: Strategic substitutes and complements". In: *Journal of Political economy* 93.3, pp. 488–511.

Card, David and Alan B Krueger (2000). "Minimum wages and employment: a case study of the fast-food industry in New Jersey and Pennsylvania: reply". In: *American Economic Review* 90.5, pp. 1397–1420.

Casini, Alessandro and Pierre Perron (2018). "Structural breaks in time series". In: *arXiv preprint arXiv:1805.03807*.

Cheng, Leonard (1985). "Comparing Bertrand and Cournot equilibria: a geometric approach". In: *The RAND Journal of Economics*, pp. 146–152.

Connor, John M (1998). "The global citric acid conspiracy: Legal-economic lessons". In: *Agribusiness: An International Journal* 14.6, pp. 435–452.

— (2001). ""Our customers are our enemies": the lysine cartel of 1992–1995". In: *Review of Industrial Organization* 18.1, pp. 5–21.

Crede, Carsten J (2019). "A structural break cartel screen for dating and detecting collusion". In: *Review of Industrial Organization* 54.3, pp. 543–574.

d'Aspremont, Claude, Alexis Jacquemin, Jean Jaskold Gabszewicz, and John A Weymark (1983). "On the stability of collusive price leadership". In: *Canadian Journal of economics*, pp. 17–25.

Deneckere, Raymond and Carl Davidson (1985). "Incentives to form coalitions with Bertrand competition". In: *The RAND Journal of economics*, pp. 473–486.

Dixit, Avinash (1986). "Comparative statics for oligopoly". In: *International Economic Review*, pp. 107–122.

Donsimoni, M-P, Nicholas S Economides, and Herakles M Polemarchakis (1986). "Stable cartels". In: *International economic review*, pp. 317–327.

Ellison, Glenn (1994). "Theories of cartel stability and the joint executive committee". In: *The Rand journal of economics*, pp. 37–57.

Friederiszick, Hans W, Frank P Maier-Rigaud, et al. (2007). "The role of economics in cartel detection in Europe". In: *The More Economic Approach in European Competition Law, D. Schmidtchen, M. Albert, S. Voigt (eds). Tübingen: Mohr Siebeck*.

Friedman, James W (1971). "A non-cooperative equilibrium for supergames". In: *The Review of Economic Studies* 38.1, pp. 1–12.

Geist, Alexander and Korbinian von Blanckenburg (2011). "Cartel detection - Is market share volatility a significant indicator?" In: *Intereconomics* 46.4, pp. 217–221.

Genesove, David and Wallace P Mullin (2001). "Rules, communication, and collusion: Narrative evidence from the Sugar Institute case". In: *American Economic Review* 91.3, pp. 379–398.

Green, Edward J and Robert H Porter (1984). "Noncooperative collusion under imperfect price information". In: *Econometrica: Journal of the Econometric Society*, pp. 87–100.

Grout, Paul A and SMIA Sonderegger (2007). "Structural approaches to cartel detection". In: *European Competition Law Annual: 2006. Enforcement of Prohibition of Cartels*. Hart Publishing, pp. 83–103.

Harrington Jr, Joseph E (2004). "Cartel pricing dynamics in the presence of an antitrust authority". In: *RAND Journal of Economics*, pp. 651–673.

Harrington Jr, Joseph E (2006a). "Behavioral screening and the detection of cartels". In: *European competition law annual*, pp. 51–68.

— (2006b). *How do cartels operate?* Now Publishers Inc.

— (2008). "Optimal corporate leniency programs". In: *The Journal of Industrial Economics* 56.2, pp. 215–246.

Harrington Jr, Joseph E, Kai Hüschelrath, and Ulrich Laitenberger (2018). "Rent sharing to control noncartel supply in the German cement market". In: *Journal of Economics & Management Strategy* 27.1, pp. 149–166.

Hay, George A and Daniel Kelley (1974). "An empirical survey of price fixing conspiracies". In: *The Journal of Law and Economics* 17.1, pp. 13–38.

Heeb, Randal D, William E Kovacic, Robert C Marshall, and Leslie M Marx (2009). "Cartels as two-stage mechanisms: Implications for the analysis of dominant-firm conduct". In: *Chi. J. Int'l L.* 10, p. 213.

Hüschelrath, Kai and Tobias Veith (2016). "Cartelization, cartel breakdown, and price behavior: Evidence from the German cement industry". In: *Journal of Industry, Competition and Trade* 16.1, pp. 81–100.

Igami, Mitsuru and Takuo Sugaya (2021). "Measuring the incentive to collude: The vitamin cartels, 1990-1999". In: *The Review of Economic Studies*.

Inderst, Roman, Frank P Maier-Rigaud, and Ulrich Schwalbe (2014). "Umbrella effects". In: *Journal of Competition Law and Economics* 10.3, pp. 739–763.

Kovacic, William E, Robert C Marshall, Leslie M Marx, and Halbert L White (2011). "Plus factors and agreement in antitrust law". In: *Mich. L. Rev.* 110, p. 393.

Marshall, Robert C, Leslie M Marx, Lily Samkharadze, and Maarten Pieter Schinkel (2016). "Monopolization conduct by cartels". In: *Discussion Paper*.

Milgrom, Paul and John Roberts (1990). "Rationalizability, learning, and equilibrium in games with strategic complementarities". In: *Econometrica: Journal of the Econometric Society*, pp. 1255–1277.

Miller, Nathan H and Matthew C Weinberg (2017). "Understanding the price effects of the MillerCoors joint venture". In: *Econometrica* 85.6, pp. 1763–1791.

Montero, Juan-Pablo and Juan Ignacio Guzman (2010). "Output-Expanding Collusion In The Presence Of A Competitive Fringe". In: *The Journal of Industrial Economics* 58.1, pp. 106–126.

Porter, Robert H (1983). "A study of cartel stability: the Joint Executive Committee, 1880-1886". In: *The Bell Journal of Economics*, pp. 301–314.

— (2005). "Detecting collusion". In: *Review of Industrial Organization* 26.2, pp. 147–167.

Porter, Robert H and J Douglas Zona (1993). "Detection of bid rigging in procurement auctions". In: *Journal of political economy* 101.3, pp. 518–538.

Quandt, Richard E (1960). "Tests of the hypothesis that a linear regression system obeys two separate regimes". In: *Journal of the American statistical Association* 55.290, pp. 324–330.

Rotemberg, Julio J and Garth Saloner (1986). "A supergame-theoretic model of price wars during booms". In: *The American economic review* 76.3, pp. 390–407.

Salant, Stephen W, Sheldon Switzer, and Robert J Reynolds (1983). "Losses from horizontal merger: the effects of an exogenous change in industry structure on Cournot-Nash equilibrium". In: *The Quarterly Journal of Economics* 98.2, pp. 185–199.

Shaffer, Sherrill (1995). "Stable cartels with a Cournot fringe". In: *Southern Economic Journal*, pp. 744–754.

Takayama, Akira (1985). *Mathematical economics*. Cambridge university press.

Topkis, Donald M (1995). "Comparative statics of the firm". In: *Journal of Economic Theory* 67.2, pp. 370–401.

— (1998). *Supermodularity and complementarity*. Princeton university press.

Wald, A (1980). "A method of estimating plane vulnerability based on damage of survivors, CRC 432, July 1980". In: *Center for Naval Analyses*.

Werden, Gregory J (2003). "Economic evidence on the existence of collusion: Reconciling antitrust law with oligopoly theory". In: *Antitrust LJ* 71, p. 719.

Appendix B

Appendix Chapter 2

B.1 Theoretical framework

B.1.1 Preliminaries

The present section demonstrates how output can avoid the parallel conduct issues which make price movements unsatisfactory as economic evidence. Older models of cartel stability overestimate the price-cutting incentive for outsiders by assuming goods are homogeneous or outsiders are price takers. A more realistic approach is to assess the effect of cartel formation within the context of differentiated products and strategic outsiders.

Based on the previous discussion of the truck market, I investigate changes in output under collusion in a Bertrand model of oligopoly. The payoff function of each firm is its profit

$$\pi_i(\mathbf{p}) = q_i(\mathbf{p})p_i - C_i(q_i), \tag{B.1}$$

with $\mathbf{p}$ denoting a vector of all prices. $C_i(q_i)$ and $q_i(\mathbf{p})$ are twice continuously differentiable functions of total cost and demand. In order to ease the analysis, I impose a number of reasonable assumptions similar to Cheng (1985):

A1. *Goods are both normal goods and gross substitutes such that* $\frac{\partial q_i}{\partial p_i} \leq 0$ *with strict inequality if* $q_i > 0$ *and* $\frac{\partial q_i}{\partial p_j} \geq 0$ *with strict inequality if* q_i *and* q_j *are positive.*

A2. *When the price of one product increases, some demand leaves the market, such that* $-\frac{\partial q_i}{\partial p_i} \geq \sum_{j \neq i} \frac{\partial q_j}{\partial p_i}$ *with strict inequality if* $q_i > 0$.

A3. *Prices are strategic complements (Bulow et al., 1985), meaning* $\frac{\partial^2 \pi_i}{\partial p_i \partial p_j} \geq 0$ *with strict inequality if* q_i *and* q_j *are positive and* $\frac{\partial^2 \pi_i}{\partial p_i} \leq 0$ *with strict inequality if* $q_i > 0$.

From A2, it follows that the Jacobian of demand is a strict diagonally dominant matrix with a negative diagonal and positive off-diagonal.

definition 2. (Strict Diagonal Dominance). *A matrix* $\mathbf{A}$ *of order* n *is strictly diagonally dominant if*

$$|a_{ii}| > \sum_{j \neq i} |a_{ij}|$$

for each row $i = 1, ..., n$.

A3 implies that each player's reaction function is upward sloping in the other player's prices, which is a reasonable assumption if goods are gross substitutes. Intuitively, if one player sets a higher price, some demand is redirected to the other players as goods are gross substitutes, which in turn incentivizes those players to increase their own prices. This property ensures that if one firm is incentivized to increase its prices for any reason, this effect is expected to be mirrored by its competitors, thereby illustrating the shortcomings of parallel conduct in price as economic evidence. Following Amir and Grilo (2003), we restrict consideration to prices above marginal costs and below a certain natural upper bound. As each player's strategy set is therefore a compact subset of $\mathbb{R}$, it also follows from A3 that the game is supermodular, meaning there exists at least one Nash equilibrium (Topkis, 1998).

B.1.2 A static model

As a first step, I examine changes for outsider firms in a static model of Bertrand oligopoly with linear demand and constant marginal costs. Let assumptions A1-A2 be satisfied. Consider an industry consisting of $n + m$ firms, with each firm $i = 1, ..., n + m$ maximizing its individual profit

$$\pi_i = q_i(\mathbf{p})(p_i - c_i), \tag{B.2}$$

and c_i denoting the marginal cost of product i. Demand is a function of all prices on the market, denoted as a $1 \times n + m$ vector $\mathbf{p}$. As demand is linear and costs are constant, it is easily verified that A3 holds and the game is supermodular, with non-zero outputs as long as costs are not prohibitively high. Furthermore, there

exists a unique pure-strategy Nash equilibrium.[1]

A competitive Bertrand-Nash equilibrium is characterized by the following system of equations

$$\frac{\partial \pi_i}{\partial p_i} = \frac{\partial q_i}{\partial p_i}(p_i - c_i) + q_i(\mathbf{p}) = 0, \qquad \forall i \in \{1, ..., n+m\}. \tag{B.3}$$

Denote the solution to this system as $\mathbf{p}_1^* = \{p_1^*, ..., p_{n+m}^*\}$ and $\mathbf{q}_1^* = \{q_1^*, ..., q_{n+m}^*\}$. Without loss of generality, suppose the first n firms form a cartel, meaning the m remaining firms are outsiders, with $n, m \in \mathbb{N}$, $m > 0$ and $n > 1$. It is assumed that the n colluding firms act as a monopolist and maximize joint profits.[2] In the unique collusive Nash equilibrium, the following first-order conditions hold

$$\frac{\partial \pi_i}{\partial p_i} = \frac{\partial q_i}{\partial p_i}(p_i - c_i) + q_i(\mathbf{p}) + \sum_{j \neq i}^{n} \frac{\partial q_j}{\partial p_i}(p_j - c_j) = 0, \qquad \forall i \in \{1, ..., n\}, \tag{B.4}$$

$$\frac{\partial \pi_i}{\partial p_i} = \frac{\partial q_i}{\partial p_i}(p_i - c_i) + q_i(\mathbf{p}) = 0, \qquad \forall i \in \{n+1, ..., n+m\}. \tag{B.5}$$

Denote the solution to this system as $\mathbf{p}_2^* = \{p_1^* + d_1, ..., p_{n+m}^* + d_{n+m}\}$ and $\mathbf{q}_2^* = \{\tilde{q}_1^*, ..., \tilde{q}_{n+m}^*\}$, with $d_i \in \mathbb{R}$. Taking a first-order Taylor approximation to q_i around $\mathbf{p}_1^*$ yields

$$q_i(\mathbf{p}) = q_i^* + \sum_{j=1}^{n+m} \frac{\partial q_i}{\partial p_j}(p_j - p_j^*). \tag{B.6}$$

As demand is linear, (B.6) holds with equality. Using this property, it is possible to solve for the collusive equilibrium in terms of the competitive equilibrium, which yields the following results.

Proposition 2. *The vector* $\mathbf{d} = \begin{bmatrix} d_1 & ... & d_{n+m} \end{bmatrix} \geq 0$ *with at least one* $d_i \in \mathbf{d} > 0$.

Proof. For notational simplicity, the derivative of demand for good i with respect to the price of good j is written as α_{ij}. Plugging $\mathbf{p}_2^*$ into (B.6) yields

$$\tilde{q}_i^* \equiv q_i(\mathbf{p}_2^*) = q_i^* + \sum_{j=1}^{n+m} \alpha_{ij} d_j. \tag{B.7}$$

[1] This follows from a diagonal dominance condition by Milgrom and Roberts (1990), p. 1271; eq. (6), which is satisfied under A1-A3.

[2] although the results are easily generalized to specifications were colluding firms place differing weights on the profits of their co-conspirators, e.g. Miller and Weinberg (2017).

Substituting (B.7) into (B.5) yields

$$\alpha_{ii}(p_i^* + d_i - c_i) + q_i^* + \sum_{j=1}^{n+m} \alpha_{ij} d_j = 0, \tag{B.8}$$

from which we can subtract the first-order condition in the competitive equilibrium, such that

$$2\alpha_{ii} d_i + \sum_{j \neq i}^{n+m} \alpha_{ij} d_j = 0. \tag{B.9}$$

A similar process can be repeated for the colluding firms, resulting in the following equation

$$2\alpha_{ii} d_i + \sum_{j \neq i}^{n+m} \alpha_{ij} d_j + \sum_{j \neq i}^{n} \alpha_{ji} d_j = \underbrace{-\sum_{j \neq i}^{n} \alpha_{ji}(p_j^* - c_j)}_{\lambda_i}. \tag{B.10}$$

Profits are assumed positive in the competitive equilibrium, meaning $\lambda_i < 0$. Using matrix notation, equations (3.6) and (3.8) yield the following system of $m + n$ equations

$$\mathbf{O}\mathbf{d}' = \underbrace{\begin{bmatrix} \lambda_1 & \dots & \lambda_n & 0 & \dots & 0 \end{bmatrix}'}_{\Lambda}, \tag{B.11}$$

with

$$o_{ij} = \begin{cases} 2\alpha_{ij} & \text{if } i = j, \\ \alpha_{ij} + \alpha_{ji} & \text{if } i \neq j \leq n, \\ \alpha_{ij} & \text{if } i \neq j > n, \end{cases}$$

From A1 and A2, it follows that $\mathbf{O}$ is strictly diagonally dominant with a negative diagonal and positive off-diagonal, meaning it is non-singular (Levy-Desplanques). As a result, (B.11) can be re-arranged as

$$\mathbf{d} = \mathbf{O}^{-1}\Lambda, \tag{B.12}$$

and from Takayama (1985) [theorem 4.D.3] it follows that $o_{ij}^{-1} \leq 0$ for each i, j. At least one entry is non-zero as long as goods are not perfect substitutes.[3]

If $\lambda_i < 0$, then $\mathbf{d} \geq 0$. It suffices to show that at least one non-zero element of $\mathbf{O}^{-1}$ is multiplied with a non-zero element of Λ to prove that there exists at least

[3]The elements of $\mathbf{O}^{-1}$ are less than or equal to zero except in the corner case where goods are

one $d_i > 0$, meaning price increases in the collusive equilibrium. If prices increase, it follows from A2 that total demand decreases.

Re-write the square matrix $\mathbf{O}$ as a block matrix consisting of four blocks, such that

$$\mathbf{O} = \begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix}. \tag{B.14}$$

Under A2, $\mathbf{A}$ and $\mathbf{D}$ are invertible, meaning block Cholesky decomposition can be used to show that

$$\mathbf{O}^{-1} = \begin{bmatrix} (\mathbf{A} - \mathbf{B}\mathbf{D}^{-1}\mathbf{C})^{-1} & \mathbf{0} \\ \mathbf{0} & (\mathbf{D} - \mathbf{C}\mathbf{A}^{-1}\mathbf{B})^{-1} \end{bmatrix} \begin{bmatrix} \mathbf{I} & -\mathbf{B}\mathbf{D}^{-1} \\ -\mathbf{C}\mathbf{A}^{-1} & \mathbf{I} \end{bmatrix}, \tag{B.15}$$

meaning the top left block of the inverse of $\mathbf{O}^{-1}$ is an inverse matrix itself and at least one element is non-zero. Should the number of colluding firms be greater than or equal to the number of outsiders, this means that a non-zero element in the top left block of $\mathbf{O}^{-1}$ is multiplied with a non-zero element in Λ. Should the number of colluding firms be less than the number of outsiders, one can again partition the matrix $\mathbf{A}$, and so on, to realize that a non-zero element in Λ is multiplied with a non-zero element in $\mathbf{O}^{-1}$, meaning there exists at least one $d_i > 0$. □

Corollary 2.1. *From A3 and proposition 2, it follows that* $\mathbf{d} > 0$.

Corollary 2.2. *From A2 and proposition 2, it follows that* $\sum_{i=1}^{n+m} \tilde{q}_i^* < \sum_{i=1}^{n+m} q_i^*$ *as total demand decreases.*

Subtracting the first-order condition for outsider i in the competitive equilibrium (B.3) from his first-order condition in the collusive equilibrium (B.5) yields

$$\tilde{q}^* = q^* - \frac{\partial q_i}{\partial p_i} d_i. \tag{B.16}$$

perfect subsitutes. Note that

$$\lim_{b \to \infty} b \begin{bmatrix} -1 & 1 & \dots & 1 \\ 1 & \ddots & & \vdots \\ \vdots & & -1 & 1 \\ 1 & \dots & 1 & -1 \end{bmatrix} \frac{1}{b} \begin{bmatrix} -1 & 1 & \dots & 1 \\ 1 & \ddots & & \vdots \\ \vdots & & -1 & 1 \\ 1 & \dots & 1 & -1 \end{bmatrix}^{-1} = \mathbf{I}. \tag{B.13}$$

As goods become better substitutes, the elements of $\mathbf{O}^{-1}$ converge to zero. Correspondingly, when looking at the system characterized by equation (B.3) for each firm, it is easily calculated that in equilibrium price equals marginal cost when $\lim_{b \to \infty}$ and there is no product differentiation.

From corollary 2.1 and A1, it follows that individual demand for the outsider firms increases. From corollary 2.2, it then follows that outsider market share necessarily increases and, as a consequence, the cartel's market share decreases.

It should be noted that although the cartel's market share necessarily decreases, it can not be ruled out that the output, and as a result the market share, of certain colluding firms can increase in the collusive equilibrium relative to competition. This would in turn imply that Blair and Romano's (1989) test, although valid in the case of homogenous products, is not universally applicable. Intuitively, this is due to the fact that when maximizing joint-profits, the cartel will be reallocate demand towards firms for which demand is less elastic.

Proposition 3. *While* $\sum_{i=n+1}^{n+m} \tilde{q}_i^* < \sum_{i=n+1}^{n+m} q_i^*$*, it can be the case that* $\tilde{q}_i^* > q_i^*$*, with* $i = n+1, ..., n+m$*.*

Proof. This is easily shown using a simple example with $n = 2$ and $m = 1$. Take

$$\mathbf{O} = \begin{bmatrix} -7 & 4 & 1 \\ 1 & -8 & 1 \\ 4 & 2 & -7 \end{bmatrix}, \tag{B.17}$$

and a linear demand function of the form $q_i = \sum_j \alpha_{ij}^{-1} q_j$, meaning the change in player one's output in the collusive equilibrium is positive (0.283). □

The previously derived results suggest that when conduct switches from competition to collusion, prices increase across the board, but each outsider gains a larger share of the market, at the expense of the cartel.

B.1.3 Dynamic adjustment

Under the restrictive assumption that demand is linear and costs are constant, outsider market share increases after a cartel is formed. Can these results be generalized? Dixit (1986) notes that it is difficult to perform comparative statics in oligopoly models with product heterogeneity, as these tend to not yield general results. Topkis (1995), Bernstein and Federgruen (2004) and other contributions find that monotonicity properties in supermodular games differ depending on the sign of first and second derivatives and that industry responses vary depending on the functional form of cost and demand.

A sufficient (but not necessary) condition for the previously derived result to hold is that firms respond to an increase in demand by raising their price to such

a degree that demand does not decrease. Apart from constant marginal costs and linear demand, this assumption nests a large number of functional forms.

A4. *Each firm's reaction funtion* $p_i(p_{-i})$ *satisfies*

$$q_i(p_i(p_{-i}), p_i) \leq q_i(p_i(\tilde{p}_{-i}), \tilde{p}_{-i}) \quad \textit{if} \quad \tilde{p}_{-i} \geq p_{-i}.$$

The reasoning is straightforward when considering a dynamic adjustment process, in which each firm plays its optimal strategy in an iterated manner. Milgrom and Roberts (1990) demonstrated that in supermodular games, the bounds on eventual behaviour resulting from such an adjustment process coincide with the existing Nash equilibria. Let the starting point be the competitive equilibrium after a cartel is formed. As goods are gross substitutes (A1), a cartel is incentivized to increase its price. Each outsider will then respond by increasing its price (A3), but not to such a degree that their demand decreases (A4). After convergence, the outsider's demand has increased, whereas total demand has decreased (A2). As a result, their market share necessarily increases at the cartel's expense.

Although this result does not necessarily hold under all possible specifications for demand and cost, it seems plausible enough as the essential requirement is a sufficiently well-behaved industry where a positive shock to demand results in both an increase in output and higher prices, which from a macro-economic perspective is a standard assumption. Although A4 is not a necessary condition, it is not possible to make informative statements about market shares without imposing a specific functional form for demand and cost.

B.1.4 A formal approach

let $n - 1 \geq 2$ firms form a cartel, meaning there is one outsider firm, assuming the existence of a unique collusive equilibrium, denoted $\mathbf{p}_c$. In order to compare outcomes under collusion to those under competition, consider the earlier discussed dynamic adjustment process in which the cartel increases its price while taking the price of its competitor as given, resulting in a new vector $\mathbf{p}_1 \geqq \mathbf{p}_0$, after which the outsider chooses his best response, resulting in $\mathbf{p}_2 \geqq \mathbf{p}_1$, and so on. As the collusive equilibrium is assumed unique, this means the game is dominance solvable and $\lim_{t\to\infty} \mathbf{p}_t = \mathbf{p}_c$ for any starting point.

The difference in player i's output after adjustment at time t is written as

$$\Delta_t^i \equiv q_i(\mathbf{p}_{t-1}) - q_i(\mathbf{p}_t) \leq 0 \tag{B.18}$$

with the inequality following from A1 and A3. Denote the demand redirected from i to j after adjustment as $\Delta_t^{i\to j}$ such that

$$\Delta_t^{i\to j} = q_j(\mathbf{p}_{t-1}) - q_j(\mathbf{p}_t) \geq 0 \tag{B.19}$$

Let the superscripts c, o and l denote the cartel, the outsider and the outside option respectively. After each adjustment by player i at time t, her change in output can be decomposed as

$$\Delta_t^i \equiv \Delta_t^{i\to j} + \Delta_t^{i\to l}, \tag{B.20}$$

with some fraction being redirected to player j and some fraction leaving the market. From A1-A4 it follows that

$$\Delta_{t+1}^i \equiv \Delta_{t+1}^{i\to j} + \Delta_{t+1}^{i\to l} \leq \Delta_t^{j\to i} < \Delta_t^j, \tag{B.21}$$

for each $t \in \mathbb{N}_0$. Once the cartel is formed at time $t = 1$, it is incentivized to increase prices, redirecting some demand $\Delta_1^{c\to o}$ to the outsider under A1, with some demand $\Delta_1^{c\to l}$ leaving the market due to A2. In response, under A3 the outsider increases its prices at $t = 2$, but Δ_2^o is at most equal to $\Delta_1^{c\to o}$ under A4 and therefore necessary smaller than Δ_1^c. At time $t = 3$, the cartel increases its price in response, but following the same logic $\Delta_3^c \leq \Delta_2^{o\to c}$, and so on. As a result

$$\sum_{t=1}^{\infty} \Delta_{t+1}^o \leq \sum_{t=1}^{\infty} \Delta_t^{c\to o} \quad \text{and} \quad \sum_{t=1}^{\infty} \Delta_{t+1}^{o\to c} < \sum_{t=1}^{\infty} \Delta_t^c, \tag{B.22}$$

as both series on the left- and right-hand side of the inequalities converge.[4] From (B.22) it follows that

$$q_o(\mathbf{p}_c) \equiv q_o(\mathbf{p}_0) - \sum_{t=1}^{\infty} \Delta_{t+1}^o + \sum_{t=1}^{\infty} \Delta_t^{c\to o} \geq 0, \tag{B.24}$$

[4] To see that the series converges, note that the d'Alembert criterion

$$\limsup_{n\to\infty} \frac{|a_{n+1}|}{|a_n|} < 1, \tag{B.23}$$

which is a sufficient condition for absolute convergence of a series $a_1 + a_2 + ...$, is satisfied.

$$q_c(\mathbf{p}_c) \equiv q_c(\mathbf{p}_0) - \sum_{t=1}^{\infty} \Delta_t^c + \sum_{t=1}^{\infty} \Delta_{t+1}^{o \to c} < 0. \tag{B.25}$$

After the cartel is formed the outsider's demand does not decrease, whereas the cartel loses some demand, meaning the market share of the outsider necessarily increases at the cartel's expense. Prices increase for both the cartel and the outsider, but market shares move in opposite directions. What happens if A4 is not satisfied? From (3.7) and (B.25) it follows that the outsider's market share increases if

$$q_o(\mathbf{p}_0)\left(\sum_{t=1}^{\infty} \Delta_{t+1}^{o \to c} - \sum_{t=1}^{\infty} \Delta_t^c\right) < q_c(\mathbf{p}_0)\left(\sum_{t=1}^{\infty} \Delta_t^{c \to o} - \sum_{t=1}^{\infty} \Delta_{t+1}^{o}\right) \tag{B.26}$$

Note that the term within brackets on either side of the equation are necessarily either positive on one side and negative on the other, or negative on both sides. Should it be the case that it is positive on the left-hand side, it is easily seen that the inequality never holds as outputs are positive. Should A4 be satisfied, then the inequality is also necessarily satisfied.

Should both terms be negative, the inequality states that the competitive output of the outsider multiplied by the cartel's output change needs to be less than the cartel's competitive output multiplied by the outsider's loss. This inequality is more likely to hold if the outsider possessed a larger market share before the cartel was formed and if the goods produced by the outsider are better substitutes for the cartel than vice versa. It seems likely that there exists a trade-off between both effects, as on the one hand firms with a larger market share are assumed to be more likely to form a cartel (Bos and Harrington Jr, 2010), meaning outsiders will generally produce less. On the other hand, larger firms might be more likely to sell closer substitutes, as outsiders focus more on niche demand.

3

By object or by effect? The potential harm of first refusal contracts.

This chapter was co-authored with Patrick Van Cayseele.

3.1 Introduction

Article 101 TFEU distinguishes between two types of prohibited agreements. On the one hand, so-called hardcore infringements refer to practices which have as their only reasonable purpose the restriction of competition, rendering them unlawful 'by object'. Explicit reference is made to price fixing agreements, production quotas or geographical division of markets. On the other hand, practices which are *prima facie* not collusive are considered to be violations of competition law if they result in similar anti-competitive outcomes, rendering them unlawful 'by effect'. Many other systems of competition law make a similar distinction.

When it comes to the latter type of agreement, economic analysis is required to demonstrate how it might distort competition. In this chapter, we investigate first refusal contracts, henceforth FRCs, which are not forbidden by object, but in many respects may result in a similar outcome to prohibited agreements. A FRC is a contractual agreement between two parties, which we will refer to as the (female) buyer and the (male) seller. Under this type of agreement, the buyer obtains a right of first refusal on some or all of the seller's assets, meaning the seller is obligated to offer his business to the buyer before he can engage in transactions with a third party.

We restrict attention to FRCs which grant the buyer a "fixed price" right of refusal, allowing her to purchase the seller's assets at a previously negotiated price. This type of contract can be distinguished from a second type of FRC, where the rightholder is allowed to match the offer of a third party (Mitchell, 2001). FRCs have been investigated in the past by Van Cayseele and Furth (1996) and Van Cayseele and Furth (2001) for a duopoly competing in prices. In the present chapter, we propose a theory of harm by investigating a homogenous Cournot industry and contrast the outcome under cooperation with the one which arises when two competitors conclude a FRC. Doing so allows us to address issues about the willingness to participate in collusive agreements compared to the inclination to engage in FRCs.

More specifically, we compare outcomes arising under a FRC to those resulting from joint-profit maximization between two firms. The results are remarkable, as they show that FRCs result in an identical loss in consumer welfare, while simultaneously remaining a blind spot to antitrust authorities. In this sense, we relate FRCs to mergers, which are always scrutinized by competition authorities. At the core of merger analysis lies the trade-off between higher market power due to increased concentration and lower costs due to efficiency gains (Perry and Porter, 1985).

Following Farrell and Shapiro (1990), mergers which do not result in productive efficiencies are assumed to decrease consumer welfare. If FRCs result in outcomes similar to (or worse than) mergers, this would suggest that they require at least the same level of scrutiny.

In addition to this, we introduce bargaining power as a possible source of concern, as FRCs are predominantly concluded when one party obtains some type of bargaining advantage over the other. In doing so, we relate potential distortions of competition resulting from FRCs to abuses of bargaining power and contribute to the debate on whether or not such abuses qualify as part of competition law. If bargaining asymmetries allow one party to improve its position at the expense of another, it is not always clear if this qualifies as a distortion of competition or simply 'competition on the merits' (Vickers, 2005). This is especially the case when alleged abuses cannot be linked directly to a loss in consumer welfare, as the stated goal of competition law is to protect competition, not competitors. If firms use a superior bargaining position to impose first refusal clauses, the loss in consumer welfare follows from the proposed theory of harm.

Lastly, while we restrict our analysis to a horizontal setting in which direct competitors engage in FRCs, this does not rule out distortive effects in a vertical setting, where a downstream buyer negotiates a FRC with an upstream seller. In a final section, we therefore consider the potential fallout resulting from FRCs in vertical competition and, in doing so, provide a number of avenues for future research to explore.

The rest of this chapter is structured as follows. Section 3.2 discusses the workings of FRCs using the Russian diamond industry as a lead example, after which section 3.3 presents a theory of harm. Anti-competitive effects are investigated using a buyout game and compared with the outcomes which arise when firms cooperate. Section 3.4 expands the scope of the effects of FRCs to abuses of bargaining power, followed by a discussion on enforcement in section 3.5. Sections 3.6 briefly considers other potential outcomes resulting from FRCs, including those in a vertical setting, after which section 3.7 concludes.

3.2 The right of first refusal

First refusal clauses are found in numerous settings, including employment contracts, real estate, oil/gas leases and commodity markets (Mitchell, 2001). Conventional

wisdom suggests that FRCs serve to prevent the breakdown of bargaining[1] or sale to an undesirable party (Walker, 1999). However, other cases demonstrate that these contracts might be signed with a more sinister intent. One such example is given by Van Cayseele and Furth (1996):

> "They are well known to exist in the diamond industry, where De Beers has this type of contract with the Russian Precious Metals Committee (PMC). In 1991, the central diamond selling organization of De Beers (CSO) reached an agreement with PMC that for a five-year period all uncut Russian diamonds not intended for industrial use would be offered first to CSO. It is only after a 'first-refusal' by CSO that PMC can offer these diamonds to other parties."

The Russian diamond industry offers clear insights into why FRCs might result in a distortion of competition. De Beers was known for artificially creating scarcity and inflating prices. Bergenstock and Maskulka (2001) note that "De Beers' operating strategy has been pure and simple: to restrict the number of diamonds released into the market in any given year and perpetuate the myth that they are scarce and should therefore command high prices". FRCs facilitated this strategy by offering De Beers the opportunity to buy stones before they were entered into the market.

The Russian diamond industry also provides a good empirical illustration of the effect of FRCs on prices. In the 1990s, Russian diamonds accounted for over a quarter of the total trade by value, with almost all of them produced in the autonomous republic of Sakha-Yakutia in Northeastern Siberia. However, the Russian Federation's financial troubles following the dissolution of the Soviet Union encouraged some of its leaders to illicitly leak diamonds onto the market, in breach of the FRC. In 1992, the PMC lost control over its Siberian diamond mines as local governments began selling these diamonds directly to the market, bypassing De Beers.

Bergenstock, Deily, et al. (2006) study the effect of the Russian leaks on the diamond price and De Beers' purchasing behavior. These leaks were done in a clandestine fashion, meaning there is no data available on either timing or size. To circumvent this issue, the authors use Russia's government deficit as a proxy for

[1]The main line of reasoning as summarized by Walker (1999) is as follows:"The contracting parties do sacrifice some upside potential if outsiders who value the property highly at the time of sale are driven away, but ex ante the parties are more concerned about the possibility that the rightholder will have the highest value at sale time, and that something could go wrong in a negotiation between the seller and the rightholder that would jeopardize the high insider value."

the state of the Russian economy. As these leaks were economically motivated, the authors assume that their size and frequency increased when the economy struggled, increasing the need for hard currency.

They find that the Russian budget deficit is positively correlated with CSO inventory, with a one billion dollar increase in the deficit corresponding to a 1% increase in inventory. In order to keep prices at their inflated level, De Beers reacted by increasing both its diamond purchases on the open market and its inventory size, which was its policy at the time when faced with market setbacks in order to maintain price stability (Montpelier, 1994). Some players directly offered their output onto the market, which exerted downward pressure on the diamond price. In turn, this incentivized De Beers to further limit supply, illustrating how the FRC helped to artificially prop up prices.

3.3 A theory of harm

In this section, we contrast the gains from buying out competitors under a right of first refusal with those obtained when firms maximize joint-profits using an n-firm Cournot oligopoly model with symmetric firms producing homogenous goods. We examine FRCs within a Cournot framework, as anti-competitive outcomes are mainly assumed to be the result of the buyer exerting influence over how the seller's supply enters the market. Hence it is assumed that FRCs are particularly harmful in markets where (i) firms compete in quantities and (ii) goods are largely homogenous. Moreover, firms attempting to inflate prices by limiting supply is a practice which predominantly takes place on commodities markets, where assumptions (i) and (ii) tend to be satisfied.[2]

3.3.1 A lead example

To present the intuition underlying our main results, we start from a simple linear example. Let the inverse demand function equal $p = a - Q$, where Q is aggregate supply in the market and a is large enough so that output is positive. Each firm's objective funtion is its individual profit $\pi_j = q_j(p - c)$. In equilibrium, individual output is given by

$$q_j(n) = \frac{a - c}{n + 1}, \tag{3.1}$$

[2]Famous examples include Transworld oil on the Brent crude market, the Hunt brothers on the silver market and Marc Rich + Co's cornering of the zinc market.

which yields the market-clearing price

$$p(n) = \frac{a + nc}{n + 1}, \tag{3.2}$$

and individual profits

$$\pi_j(n) = \left(\frac{a - c}{n + 1}\right)^2. \tag{3.3}$$

Let $a = 1$ and $c = 0$, meaning (3.2) reduces to the inverse of the number of players in the market plus one. Table 3.1 depicts the equilibrium price and associated sales under a duopoly, a cartel and a FRC. Under a Cournot duopoly, the per firm profits are 1/9. A cartel agreement which maximizes joint profits is implemented by agreeing on a production quotum of $q_j = 1/4$, with the resulting industry profit (1/4) to be divided equally, thus increasing individual profits by 12.5% compared to the competitive outcome.

Table 3.1: Lead Example

	Duopoly	**Cartel**	**FRC**
p	1/3	1/2	1/2
Q	2/3	1/2	1/2
π_j	1/9	$1/2 \times 1/4$	$1/4 - 1/9$

Whenever firms enter into a FRC, the buying side can become the sole supplier, earning her the industry monopoly profit. To do so, she has to buy out the seller before he enters his output into the market. The amount at which this will be done depends on the stipulations of the contract. If the selling party offers his supply directly to the market, a profit of 1/9 is made. Therefore, if supply is offered to the buying party first, the seller's profits should at least equal 1/9. He only has this alternative, hence it constitutes his threat point. As the selling party agreed to enter into a FRC with the buyer, it is assumed (for now) that the buying party has all the bargaining power in this agreement, allowing her to keep the seller at the threat point.

This results in an outcome where the buying party earns both more than under Cournot competition and a hardcore cartel with a production quotum. The buyer's profits are equal to the industry profits under monopoly (1/4) minus the cost of buying out the seller (1/9), which constitutes an increase of 25% compared to the

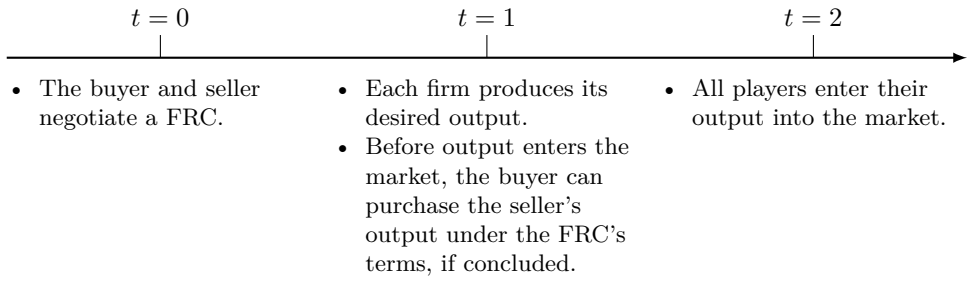
duopoly outcome. The resulting equilibrium implements a monopoly outcome even though the duopolists behave non-cooperatively. Hence, it is obvious that whenever a buying party can find a weak selling party she will not hesitate. The FRC (i) serves as a backdoor way to monopolize the industry and control supply, (ii) increasing the buyer's profits by more than what she could obtain under a cartel agreement, while (iii) remaining under the radar of an antitrust authority who cannot appeal to an offense by object.

The intuition behind the consumer harm inflicted by a FRC is straightforward. When one firm buys out another under a right of first refusal, this can equivalently be seen as a reduction in the number of players directly serving the market, resulting in higher price cost margins by the Cournot limit theorem. In this sense, a comparison can be made with both cartel formation and horizontal mergers. However, whereas merger analysis consists of weighing the gains from efficiencies against the losses due to higher market power, such efficiencies might be largely absent in the case of FRCs. Farrell and Shapiro (1990) show that, absent any cost efficiencies or synergies, a merger under Cournot competition must increase price.

3.3.2 The buyout game

We generalize the analysis by considering an n-player symmetric Cournot market with homogenous goods and constant marginal costs, but impose no explicit functional form on demand. Denote the inverse demand function as $p(Q)$, with $p'(Q) < 0$, $p''(Q) > 0$ over its domain. In the n-firm equilibrium, each player's output and profit are identical and denoted $q(n)$ and $\pi(n)$ respectively.

Figure 3.1: Timeline of the buyout game.



We consider the effect of FRCs by introducing a seller, denoted by subscript s, who can enter into a FRC with a buyer, denoted by subscript b. After production -

but before output is entered into the market - a FRC offers the buyer the option to purchase the seller's output under a right of first refusal. The price at which this is done depends on the stipulations of a previously agreed upon contract. The buyout game therefore consists of three phases, as depicted on figure 3.1. These are (i) a contracting phase, (ii) a buyout phase and (iii) a market phase in which firms simultaneously compete in quantities.

Stage 1: the contract

Similar to Bloch's (1995) work on the formation of associations in oligopolies, we start by considering a negotiation phase, in which a seller and buyer can enter into a FRC, followed by a competitive market stage within a symmetric Cournot model. However, as the main intention of this chapter is to examine the potential harm resulting from these contracts, we take a mostly agnostic stance to how any surplus resulting from the FRC is divided, denoting the fraction allotted to the seller as $\alpha \in [0, 1)$.[3]

We impose two assumptions on the contract:

1. As it is in the interest of both parties to maximize any surplus regardless of how it is divided, it is assumed that the contract implements a Pareto efficient outcome.

2. The contract satisfies either player's participation constraint, meaning neither party is worse off compared to the status quo.

The first assumption is satisfied by most bargaining solutions in the literature, e.g. the Nash solution, the egalitarian solution, the Kalai-Smorodinsky solution, whereas the second assumption is a standard requirement in contract theory.

Graphically, figure 3.2 depicts the (zero-sum) bargaining problem over an amount of surplus, denoted g. The outside option of either party is their payoff in the n-player Cournot game, which yields the disagreement solution situated at the origin. Let the output produced by the seller be q_s. Denote the seller's (not necessarily unique) surplus maximizing strategy as

$$q_s^* = \arg\max_{q_s} g(q_s, \sigma^*(q_s)), \tag{3.4}$$

[3]For instance, Bloch (1995) assumes that the formation of associations is the outcome of a Rubinstein (1982) alternating-offer bargaining model.

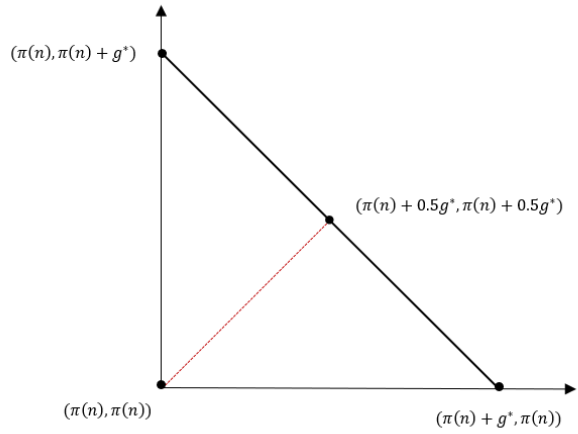


Figure 3.2: The bargaining problem.

with $g(q_s, \sigma^*(q_s))$ denoting the surplus which can be obtained from entering into a FRC if the seller's output q_s is purchased by the buyer under the stipulations of the contract, after which the buyer plays her optimal strategy $\sigma^*(q_s)$ in the subsequent stages of the game. For notational simplicity, the maximum surplus is denoted as g^*, such that

$$g^* = g(q_s^*, \sigma^*(q_s^*)). \tag{3.5}$$

Depending on how g^* is distributed, payoffs shift along the Pareto frontier as depicted on figure 3.2.

Let the (fixed price) contract be given by a mapping $\varphi : q_s, \alpha \mapsto p_s$, which determines the price p_s as a function of the seller's output and bargaining power. We decompose this price as follows

$$\varphi(q_s, \alpha) = \phi(q_s) + \frac{\alpha g(q_s, \sigma^*(q_s))}{q_s}. \tag{3.6}$$

As the function $\phi(q_s)$ represents the price the seller receives if $\alpha = 0$ and the contract implements a Pareto efficient outcome, it follows that

$$\phi(q_s^*)\big(q_s^* - \delta c\big) = \pi(n), \tag{3.7}$$

with

$$q_s^* = \arg\max_{q_s} \Big\{ \phi(q_s)\big(q_s - \delta c\big) \Big\}. \tag{3.8}$$

Equations (3.6)-(3.8) ensure that, should the buyer hold all the bargaining power, the contract still satisfies the seller's participation constraint should he play his optimal strategy. This can be considered the dictatorial solution of the buyer, as she obtains all the surplus while the seller receives a payoff equal to his outside option.

Importantly, should the buyer trigger the first refusal clause, we modify the marginal cost incurred by the seller using a parameter $\delta \in (0, 1]$, which denotes the fraction of marginal costs incurred in the production process. For instance, Mitraille and Moreaux (2013) investigate the role of inventories in a Cournot model under the assumption that marginal costs are incurred during production, meaning the cost of entering inventories into the market is reduced to zero ($\delta = 1$). We allow for a structure which nests this assumption, but also accommodates the fact that there might be logistical costs which are only incurred after production, implying a δ less than one.

Lastly, as long as entering into a FRC yields a non-negative surplus under optimal play, such that

$$g^* \geq 0, \tag{3.9}$$

the contract will satisfy either player's participation constraint.

3.3.3 Stages 2 and 3: the market

If the buyer exercises her right of first refusal, her strategy is a 2-tuple $\sigma = \{\hat{q}_b, \tilde{q}_b\}$, with $\hat{q}_b$ and $\tilde{q}_b$ denoting the amount of produced and purchased output she enters into the market respectively, such that $q_b = \hat{q}_b + \tilde{q}_b$. Her optimization problem can be stated as

$$\begin{aligned} \max_{\sigma} \quad & \pi_b \equiv \Big\{ \hat{q}_b(p - c) + \tilde{q}_b(p - \delta c) - q_s^* \phi(q_s^*) \Big\} \\ \text{s.t.} \quad & \tilde{q}_b \leq q_s^*. \end{aligned} \tag{3.10}$$

In the optimum, the constraint will hold with equality. In a one-shot setup, she gains no advantage from keeping purchased output off the market.[4] After buying out her competitor, the buyer can enter purchased output into the market at a marginal cost $(1 - \delta)c$. However, doing so will incur a fixed cost equal to the last term of the

[4] As a result, we abstract from any storage costs as discussed by Arvan (1985), although the De Beers example shows that maintaining a fluctuating stockpile can be a viable strategy. Within the confines of a static model, optimizing behaviour will always result in the buyer entering all purchased output into the market.

maximand.

This section analyses the buyer's optimal strategy in the buyout game, denoted $\sigma^* = \{\hat{q}_b^*, \tilde{q}_b^*\}$. As mentioned previously, buying out the seller will only be her equilibrium strategy if the gain from doing so is positive, which now yields the following condition

$$g^* \equiv \pi_b(q_s^*, \sigma^*(q_s^*)) - \ \pi(n) \geq 0. \tag{3.11}$$

If not, it follows from backward induction that the buyer and seller will decide not to enter into a FRC as either the buyer's - or both the buyer's and seller's - participation constraint is not satisfied.

We derive σ^* as a function of the buyer's inventory q_s^*, which is the amount she purchased from the seller under the stipulations of the FRC. Provided that purchasing costs are sunk, the possession of inventories changes the buyer's strategy insofar as it changes her marginal cost. If marginal costs are firm-specific and assuming a positive interior Nash-Cournot equilibrium $\mathbf{q}^* = \{q_1^*, ..., q_n^*\}$ exists, the following first-order condition is satisfied for each $i = 1, ..., n$

$$\frac{\partial \pi_i}{\partial q_i}(q_i^*, q_{-i}^*, c_i) = p(Q^*) - c_i + q_i^* p'(Q^*) = 0, \tag{3.12}$$

with $Q^* = q_i^* + q_{-i}^*$. Solving for q_i^* yields

$$q_i^* = \frac{p(Q^*) - c_i}{-p'(Q^*)}, \tag{3.13}$$

meaning market shares decrease in marginal cost. If one firm suddenly experiences a cost decrease, it also follows that in the new equilibrium her output will increase. For a formal proof of this statement, see Bergstrom and Varian (1985) or Dixit (1986). For a discussion on the conditions under which a unique Nash equilibrium exists in a generalized (non-linear) Cournot setting with asymmetric costs, see Harris et al. (2010).

We use this property to investigate the buyer's optimal behaviour when she possesses a certain amount of inventory, which she can enter into the market at a lower marginal cost. Denote the individual equilibrium output of each player i in function of costs as $q_i^*(c_i, c_{-i})$. Suppose the buyer possesses an amount of inventory q_s^* such that $q_s^* \geq q_b^*((1-\delta)c, c)$, i.e. the equilibrium amount she would produce if she faces a lower marginal cost $(1-\delta)c$ whereas all other firms' costs stayed unchanged. Importantly, as $\delta \in (0, 1]$, it follows that $q_b^*(c, c) < q_b^*((1-\delta)c, c)$.

For the buyer, her best action is to enter purchased output into the market untill $q_b = q_b^*((1-\delta)c, c)$. The buyer operates on the reaction curve of a firm facing a lower marginal cost as long as $q_b < q_s^*$, meaning she faces the following cost function

$$c_b(q_b) = \begin{cases} c & \text{if } q_b > q_s^*, \\ (1-\delta)c & \text{if } q_b \leq q_s^*. \end{cases}$$

As long as she possesses inventory, she wil not be incentivized to produce herself. However, once the new equilibrium is reached, she will have no reason to enter additional output into the market as well.

Should she posses an amount of inventory such that $q_s^* < q_b^*(c, c)$, she will still opt to enter inventories into the market before producing herself as she can do so at a lower marginal cost $(1-\delta)c$. However, once all inventory is entered into the market, her marginal cost switches to c. As a result, she will produce output herself and $\hat{q}_b^* = q_b^*(c, c) - q_s^*$. Lastly, should $q_b^*(c, c) \leq q_s^* < q_b^*((1-\delta)c, c)$, she will enter all output into the market as $q_s^* < q_b^*((1-\delta)c, c)$, at which point she faces a switch in marginal cost such that $q_b^* = q_b^*(c, c)$. However, as her output already is greater than or equal to this amount, she will opt not to produce herself.

The buyer's optimal behavior as a function of the seller's output (her inventory) can be summarized as

$$q_b^*(q_s^*) = \begin{cases} q_b^*((1-\delta)c, c) & \text{if } q_s^* \geq q_b^*((1-\delta)c, c), \\ q_s^* & \text{if } q_b^*(c, c) < q_s^* < q_b^*((1-\delta)c, c), \\ q_b^*(c, c) & \text{if } q_s^* \leq q_b^*(c, c), \end{cases}$$

which can be disaggregated along the lines of produced output $\hat{q}_b^*$ and purchased output $\tilde{q}_b^*$ entered into the market as

$$\hat{q}_b^*(q_s^*) = \begin{cases} 0 & \text{if } q_s^* \geq q_b^*((1-\delta)c, c), \\ 0 & \text{if } q_b^*(c, c) < q_s^* < q_b^*((1-\delta)c, c), \\ q_b^*(c, c) - q_s^* & \text{if } q_s^* \leq q_b^*(c, c), \end{cases}$$

and

$$\tilde{q}_b^*(q_s^*) = \begin{cases} q_b^*((1-\delta)c, c) & \text{if } q_s^* \geq q_b^*((1-\delta)c, c), \\ q_s^* & \text{if } q_b^*(c, c) < q_s^* < q_b^*((1-\delta)c, c), \\ q_s^* & \text{if } q_s^* \leq q_b^*(c, c), \end{cases}$$

meaning the buyer only produces output herself if $q_s^* < q_b^*(c,c)$, which in the homogenous Cournot model after buying out the seller simplifies to $q_s^* < q(n-1)$.

Graphical illustration To present some visual intuition as to the effect of inventories on equilibrium outcome, figure 3.3 depicts a Cournot duopoly with linear demand, in which player One possesses a certain amount of inventory. A similar figure can be found in the literature dealing with capacity constraints, in which firms face a switch in marginal cost depending on output, e.g. Dixit (1980), Schmalensee (1981) or Tirole (1988). However, whereas inventories *increase* a firm's potential to sell, capacity constraints impose a *limit* on production.

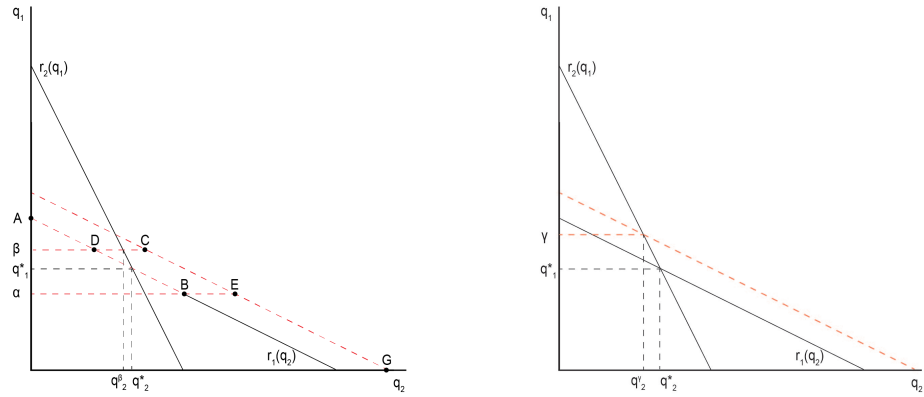


Figure 3.3: Cournot duopoly with inventory.

1. Without inventories, equilibrium is given by the intersection of the reaction curves $r_1(q_2)$ and $r_2(q_1)$, yielding equilibrium output q_1^*, q_2^*. Let the inventory of player One be α (fig.3.3a). As purchasing costs are sunk, she will enter inventory into the market untill marginal revenue equals $(1-\delta)c$. However, the amount she can enter into the market is limited, resulting in a switch in marginal cost. Introducing inventories therefore generates a kinked reaction function which is given by the line segment ABEG. Between B and E, player One's reaction curve is locally inelastic, after which it runs parallel to the original reaction curve. If inventory is below the prior equilibrium amount, firm one will produce output until the original equilibrium is reached.

2. Let her inventory be β (fig.3.3a). Player One's reaction curve is now given by the line segment ADCG, meaning she no longer produces output herself and instead offers her entire inventory to the market. Her reaction function is inelastic up to point C, meaning it mimics the behavior of a Stackelberg leader, see Mitraille and Moreaux (2013). The output of player One (Two) expands (contracts) in the new equilibrium.

3. Lastly, let her inventory be greater than γ (fig. 3.3b). Player one's reaction curve is given by shifting the original reaction curve outward, as it operates at a lower marginal cost $(1-\delta)c$. It is optimal to keep some fraction of inventory off the market unless inventory is exactly equal to γ. Again, the output of player One (Two) expands (contracts) in the new equilibrium.

As mentioned previously, if $q_s^* \geq q(n-1)$, the buyer will not produce output herself, which seems to be an unrealistic situation. We therefore restrict attention to scenarios where $q_s^* < q(n-1)$, meaning that should the buyer trigger the first refusal clause, she will produce an amount of output equal to the difference $\hat{q}_b^* = q(n-1) - q_s^*$ herself.

3.3.4 Buyout or joint-profit maximization?

Based on the previously described buyout game, we compare the gains from a strategy consisting of buying out a single competitor under a FRC with those obtained from joint-profit maximization between two firms, which is prohibited by object unless approved under merger regulation. In doing so, we demonstrate that the outcomes are identical, both with respect to the total gain of the undertaking firms and the corresponding decrease in output and loss in consumer welfare.

Re-consider the function $g(q_s, \sigma)$, which yields the surplus resulting from an FRC such that

$$g(q_s, \sigma) = \pi_b(q_s, \sigma) - \pi(n). \tag{3.14}$$

The second term on the right-hand side denotes the buyer's opportunity cost, which equals foregone profit in the n-firm equilibrium. Salant et al. (1983) use a similar function $f(m)$ to examine the gain (loss) from $m+1$ firms maximizing their joint profits

$$f(m) = \pi(n-m+1) - (m+1)\pi(n), \tag{3.15}$$

which is used as a point of comparison. The net gain from cooperation equals

joint profits in the new equilibrium, minus the opportunity costs for each of the cooperating firms.

Suppose the contract induces the seller to produce an amount identical to the one he would produce in the n-firm equilibrium, such that $q_s^* = q(n)$. Net of any surplus, the price the seller receives therefore solves

$$(p(n) - c)q(n) = (\phi(q(n)) - \delta c)q(n), \tag{3.16}$$

such that $\phi(q(n)) = p(n) - (1 - \delta)c$. In this case, it is optimal for the buyer to produce a certain amount of output herself, such that $\hat{q}_b^* = q(n-1) - q(n)$ and

$$g^* = \Big(p(n-1) - c\Big)\Big(q(n-1) - q(n)\Big) + \Big(p(n-1) - (1-\delta)c\Big)q(n) \\ - \Big(p(n) - c\Big)q(n) - \Big(p(n) - (1-\delta)c\Big)q(n). \tag{3.17}$$

The buyer sells her entire inventory at the market-clearing price $p(n-1)$ while incurring a selling expense equal to $(1-\delta)c$. When selling produced output, she incurs a higher cost c which includes production expenses. The third and fourth term on the right hand side of (3.17) equal the buyer's foregone profit in the n-firm equilibrium and the cost at which she bought out the seller respectively, net of re-distribution of the surplus.

Equation (3.17) can be re-written to obtain

$$g^* = \Big(p(n-1) - c\Big)q(n-1) - 2\Big(p(n) - c\Big)q(n) \tag{3.18}$$

$$= \pi(n-1) - 2\pi(n) = f(1). \tag{3.19}$$

The surplus from buying out one firm under a right of first refusal is equal to the gain from two firms cooperating. We can extend this result to show that as long as $q_s^* \leq q(n-1)$, the total gain from joint-profit maximization is equal to that of a buyout:

Proposition 4. *If $q_s^* \leq q(n-1)$, then $g^* = f(1)$.*

Proof. If $q_s^* \leq q(n-1)$, then

$$g^* = \Big(p(n-1) - c\Big)\Big(q(n-1) - q_s^*\Big) + \Big(p(n-1) - (1-\delta)c\Big)q_s^* \\ - \Big(p(n) - c\Big)q(n) - \phi(q_s^*)q_s^*. \tag{3.20}$$

From (3.7) it follows that

$$\phi(q_s^*) = \frac{\pi(n)}{q_s^*} + \delta c, \tag{3.21}$$

meaning (3.20) can be re-written as

$$g^* = \Big(p(n-1) - c\Big)\Big(q(n-1) - q_s^*\Big) + \Big(p(n-1) - (1-\delta)c\Big)q_s^* \\ - \Big(p(n) - c\Big)q(n) - \Big(p(n) - c\Big)q(n) - q_s^*\delta c, \tag{3.22}$$

which can be further re-written to obtain

$$g^* = \Big(p(n-1) - c\Big)q(n-1) - 2\Big(p(n) - c\Big)q(n) = f(1). \tag{3.23}$$

□

Consequently, a FRC implements an outcome identical to the one that arises when two firms maximize joint profits, as total output, prices and obtained surplus (regardless of distribution) are identical.

3.4 Bargaining power

Although buying out a competitor under a right of first refusal can yield equal gains to joint-profit maximization, Salant et al. (1983) demonstrate that - using a linear model as described in section 3.3.1 - the gain from cooperation is negative as long as the number of firms account for less than 80% of all firms on the market. As a consequence, two-firm mergers are not profitable unless duopolists merge to monopoly, despite industry profits increasing as n decreases.

There exist several articles which demonstrate how this negative result can be overcome. Hennessy (2000) shows that it derives from strong assumptions imposed on the demand function, demonstrating that under different (non-linear) demand specifications two-firm mergers can be profitable. The same goes for Hsu and Wang (2010), who introduce a degree of product differentiation, Huck et al. (2001), who investigate mergers between Stackelberg leaders and followers, or Deneckere and Davidson (1985), who look at supermodular games. For a good overview, see Gelves (2014). When it comes to FRCs, there is an additional aspect which could be of importance: bargaining power.

Given that the results of Salant et al. (1983) hold for an industry where FRCs

exists, this might lead to a stark conclusion. Previously, the assumption was maintained that the seller's outside option was the n-firm equilibrium profit. Clearly, FRCs benefit the buyer more when she finds a weak seller, i.e. a seller who faces a worse outside option. For instance, bargaining advantages could arise when a seller faces a liquidity crisis, allowing the buyer to negotiate a lower price in exchange for advance payment. Although the contract specifications between De Beers and the PMC are unknown, the deal was made at a time when Russia was "desperate for hard currency" and coincided with De Beers providing a 1 billion USD loan to Russia.[5]

A more recent example is given by the European zinc industry in which FRCs were known to exist between zinc smelter Nyrstar (seller) and commodity trader Trafigura (buyer) for Nyrstar's finished zinc metal. In 2015, Nyrstar had accumulated significant debt, causing serious liquidity constraints. At the same time, it needed to purchase zinc ore in order to keep its operations going. This led the company to search for a concentrate supplier who could also guarantee the necessary liquidity - which came in the form of advance payments (prepayment) for its finished metal - in order to fund concentrate purchases and debt repayment:

> "[...] Trafigura came out as the only realistic option that could provide the security of supply and offtake Nyrstar needed in terms of quantity and quality in the longer term as well as other terms that smelters commonly seek such as prepayment."[6]

Nyrstar minority shareholders argue that the resulting deals were set at terms which were highly disadvantageous. Nyrstar's board admitted that they were in a weak bargaining position:

> "[...] arm's length in terms of negotation is something that also represents the relative strengths of the counterparties. Nyrstar was not in a strong postion at the end of 2015. [...] There were very stark choices at the time."[7]

Indeed, the price paid for Nyrstar's finished zinc metal by Trafigura came at a "significant discount to prevailing spot-market rates".[8]

[5] Possehl, S. 14/05/1994, Diamond Deal Stirs Regret in Russia , NY Times, Section 1, Page 37. Last accessed 26/10/2022.
[6] See Nyrstar, 26/06/2020, Written questions for annual general meeting and extraordinary general meeting to be held on 30 June 2020 , p. 3. (Last accessed 26/10/2022).
[7] Ibid., p. 4.
[8] Bloomberg, 09/09/2019, Trafigura accused of throttling Nyrstar with lopsided zinc deals, (Last accessed 26/10/2022).

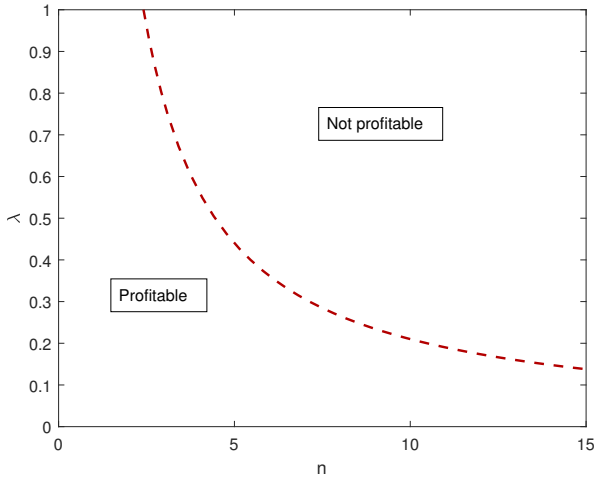


Figure 3.4: Profitable FRCs in the (n, λ) grid.

For isntance, we can introduce a measure of bargaining advantage $\lambda \in (0, 1]$ by changing the seller's threat point as follows

$$q_s^* \Big(\phi(q_s^*) - \delta c \Big) \geq \lambda \pi(n). \tag{3.24}$$

Previously, it was assumed that the seller's outside option was his profit from competing in the market. We now allow for an altered threat point, which can be interpreted as the seller needing to incur a certain cost before he can engage in the market, reducing the value of his outside option. If $q_s^* \leq q(n-1)$ and (3.24) holds with equality the buyer's gain equals

$$g^* = \pi(n-1) - (1+\lambda)\pi(n), \tag{3.25}$$

if she can keep the seller at his threat point. Staying withing the linear model employed by Salant et al. (1983) and plugging (3.3) into (3.25), it follows that $g^* > 0$ if and only if

$$\left(\frac{a-c}{n} \right)^2 - (1+\lambda) \left(\frac{a-c}{n+1} \right)^2 > 0, \tag{3.26}$$

which reduces to

$$\frac{n+1}{n} > \sqrt{1+\lambda}. \tag{3.27}$$

As $n > 0$, this inequality is satisfied if

$$\lambda \in \left[0, \frac{2n+1}{n^2}\right), \quad \text{with} \quad \lim_{n\to\infty} \frac{2n+1}{n^2} = 0. \tag{3.28}$$

When n increases, a steeper discount is required in order for the FRC to remain profitable. Figure 3.4 plots the locus for which (3.27) is satisfied with equality, demarcating the region over which FRCs are profitable.

Previously, we examined the effects of FRCs under the presumption that they could consitute an infringement of art. 101 TFEU. However, shifting attention to bargaining power might also necessitate a re-orientation towards art. 102 TFEU, which prohibits abuses by dominant firms (Vickers, 2005). Alternatively, competition authorities are increasingly scrutinizing abuses of economic dependence (or a superior bargaining position). In contrast to an abuse of dominance as prohibited by art. 102, this type of abuse results from one party obtaining a superior bargaining position relative to another, shifting attention from absolute to relative market power.

Wakui and Cheng (2015) note that, in the debate on abuse of bargaining power as part of competition law doctrine, "[t]he obvious criticism [...] is that these abuses in most cases do not seem to result in harm to competition or loss in consumer welfare". However, if firms use a superior bargaining position to impose FRCs at disadvantageous terms, potential consumer harm follows from the previously derived results.

3.5 Enforcement

Buying output from a competitor under an FRC can yield equal gains to explicit cooperation with that competitor. Moreover, cooperation is prohibited by object unless approved under merger regulation. Firms can attempt to cooperate illicitly, but there are a large number of factors which inhibit such collusive schemes, see for instance Osborne (1976). As mentioned previously, FRCs can therefore be seen as a facilitating practice, as they result in a similar outcome, while avoiding the pitfalls which hinder cooperation.

Most importantly, collusive agreements cannot be contractually enforced and need to be self-enforcing. As a result, the theoretical literature regarding cartel stability often assumes the existence of one or more punishment strategies such as Nash reversion and costly price wars, e.g. Friedman (1971) or Green and Porter

(1984). In the case of FRCs, contracts are court enforceable agreements which act as a deterrent towards cheating, whereas cartel members have no legal recourse when faced with price-cutting.

Firms can attempt to cheat on a FRC and offer output directly to the market, as evidenced by the Russian diamond industry. Indeed, the Russian case could be regarded as analogous to the classic cartel problem as posed by Friedman (1971), with profits from deviating exceeding those from adherence. In principle, contractual enforcement should prohibit deviation. This would however require the presence of adequately strong institutions, which were notably absent in Russia after the dissolution of the Soviet Union.

Contractual enforcement also avoids another problem which might destabilize collusive agreements: distribution of the spoils. For instance, Levenstein (1997) describes a bromine cartel which experienced six price wars over this question. Should a FRC result in a positive surplus, side payments are embedded in the agreement, as the seller contractually receives a percentage of this surplus as part of his buyout given that he possesses some measure of bargaining power.

In terms of returns, it could also be considered that - due to their self-enforcing nature - prohibited agreements might result in a payoff less than the one that could be obtained from a FRC. As an example, Levenstein and Suslow (2006) argue that most cartels set prices below or above the profit maximizing monopoly level, pointing towards coordination and monitoring problems as one of the main culprits. For instance, Porter (1983) shows that optimal trigger price strategies in a Cournot model can result in quantities which do not maximize joint-profits. Similarly, the presence of antitrust authorities and the desire to avoid detection might exert downward pressure on incentive compatible prices (Harrington Jr, 2004), resulting in a lower payoff.

3.6 Further discussion

3.6.1 Vertical competition

FRCs as barriers to entry One of the few examples of FRCs being scrutinized under competition law is given by the poultry sector in Zambia. A dominant firm had imposed clauses which obligated another poultry farmer to offer some of its assets to the dominant firm first, should they be put up for sale. Intervention by competition authorities resulted in both increased competition and higher entry into

the Zambian poultry sector.[9]

This case touches upon another concern raised by a FRC, which can result in a form of exclusivity resulting in barriers to entry. In this sense, a right of first refusal can be related to exclusive dealing, which generally refers to the situation where a manufacturer prohibits distributors from selling output produced by its competitors (Bernheim and Whinston, 1998) and the larger literature dealing with contracts as a barrier to entry (Aghion and Bolton, 1987). FRCs can be considered the upstream equivalent, as they have the potential to prevent new distibutors from entering the market should the buyer have a first option on manufacturer supply.

Alternatively, entry could be hindered under a non-fixed price contract. As mentioned in the introduction, a right of first refusal is a blanket term which, aside from the fixed price contracts discussed in the present chapter, also concerns contracts which allow the holder to match offers made by a third party. After a refusal to do so, the third party's offer can be considered. As an example, consider the telecommunications industry in which wireless carriers lease cell towers. Should the lessees (wireless carriers) agree to a right of first refusal with the lessor (property owner), this allows them to block any attempt by a third party from acquiring the lease by matching their offer. Examples of cases debating similar issues include the Oklahoma Gas and Electric Company,[10] Bangor Hydro-electric company[11] and T-mobile UK Limited.[12]

Cornering the market Artificially pushing up prices by buying up large quantities of a good on the spot and futures market is a risky practice as it encourages suppliers to produce and sell more. Examples of attempts to corner the market turning disastrous for the undertaking firm include Transworld oil on the Brent crude market and Marc Rich + Co's cornering of the zinc market, see Blas and Farchy (2021). Clearly, FRCs could play a facilitating role. They can be compared to a call option, where a buyer obtains the right to a certain volume of output produced by a seller at a pre-specified price, which is a crucial financial instrument to any firm trying to corner the market.

[9] see OECD, 02/10/2001, OECD Global Forum on Competition, Zambian contribution, p. 5-7. (last accessed 26/10/2022)

[10] Oklahoma Gas and Electric Co. v. FERC, No. 14-1281 (D.C. Cir. 2016), (last accessed 26/10/2022)

[11] Emeran Maine, Formerly known as Bangor Hydro-electric company, et al. v. Federal energy regulatory comission, (last accessed 26/10/2022)

[12] Case COMP/ 38.370 - O2 UK Limited / T-Mobile UK Limited ("UK Network Sharing Agreement"), (last accessed 26/10/2022)

The key difference lies in the fact that an options contract gives the buyer a right to purchase a pre-specified volume at a certain point in time. Meanwhile, a FRC grants the buyer an option on all of the seller's output, both present and future, as it forces the seller to offer any output to the buyer first. In this sense, option contracts give a seller much more leeway on how to handle its output, potentially to the detriment of a buyer attempting to control the market.

3.6.2 Other considerations

Double marginalization Double marginalization refers to the externalities resulting from market power in vertical supply chains, were each link in the chain receives a positive markup on the price it payed, resulting in a reduced consumer surplus. The outcomes resulting from FRCs could be re-interpreted as a form of double marginalization. The gain from FRCs resulted from the buyer receiving a markup on the price he payed to the seller. Consequently, within a horizontal setting, FRCs can be regarded as the horizontal equivalent.

Poison pill clauses Lastly, should this type of contract exist between a weak seller and a buyer, FRCs could contribute to the seller being kept in a state of dependence. In this sense, we relate it to poison pill strategies, which refer to tactics employed to prevent outsiders from acquiring a large or controlling stake in a company, see for instance Velasco (2003). Similarly, an FRC could prevent outside investment from taking place in a weak competitor. As investors realize that these contracts result in a form of exclusivity between buyer and seller, this could dissuade them from stepping in.

3.7 Conclusion

The present chapter investigated the collusive potential of FRCs. If competitors enter into this type of agreement willingly, it leads to the following conclusion: any benefit they derive from it could come at the expense of the consumer. However, if bargaining power is skewed towards one party, gains could also be obtained at the expense of the other. FRCs could therefore constitute an infringement of article 101 TFEU by effect, an infringement of article 102 TFEU in the case of dominance or an abuse of economic dependence in the case of relative dominance.

In the case of art. 101, it was shown that FRCs can result in a similar outcome

to joint-profit maximization between two competitors. Although we took an agnostic stance to how surplus was distributed, it was shown that outcomes are identical with regards to price, quantities and the corresponding loss in consumer welfare. When it comes to art. 102 and abuses of bargaining power, it was hypothesized that these contracts could be abused by a buyer in order to exploit a weak seller. In this sense, we establish a link between abusive conduct in a business-to-business setting and the subsequent consumer harm, suggesting that these types of prohibitions deserve their spot in competition law.

In summary, it seems that scrutinizing FRCs is not without merit. After all, competition authorities agree that approval of a merger should hinge on whether or not the benefits due to efficiencies outweigh any losses due to higher market power. If similar dynamics are at play whenever a FRC is concluded, this could call for a similar procedure.

Bibliography

Aghion, Philippe and Patrick Bolton (1987). "Contracts as a Barrier to Entry". In: *The American Economic Review*, pp. 388–401.

Arvan, Lanny (1985). "Some examples of dynamic Cournot duopoly with inventory". In: *The Rand Journal of Economics*, pp. 569–578.

Bergenstock, Donna J, Mary E Deily, and Larry W Taylor (2006). "A Cartel's response to cheating: An empirical investigation of the De Beers diamond empire". In: *Southern Economic Journal*, pp. 173–189.

Bergenstock, Donna J and James M Maskulka (2001). "The De Beers story: are diamonds forever?" In: *Business Horizons* 44.3, pp. 37–44.

Bergstrom, Theodore C and Hal R Varian (1985). "When are Nash equilibria independent of the distribution of agents' characteristics?" In: *The Review of Economic Studies*, pp. 715–718.

Bernheim, B Douglas and Michael D Whinston (1998). "Exclusive Dealing". In: *Journal of political Economy* 106.1, pp. 64–103.

Blas, Javier and Jack Farchy (2021). *The World for Sale: Money, Power, and the Traders Who Barter the Earth's Resources*. Oxford University Press.

Bloch, Francis (1995). "Endogenous structures of association in oligopolies". In: *The Rand journal of economics*, pp. 537–556.

Deneckere, Raymond and Carl Davidson (1985). "Incentives to form coalitions with Bertrand competition". In: *The RAND Journal of economics*, pp. 473–486.

Dixit, Avinash (1980). "The role of investment in entry-deterrence". In: *The Economic Journal* 90.357, pp. 95–106.

— (1986). "Comparative statics for oligopoly". In: *International Economic Review*, pp. 107–122.

Farrell, Joseph and Carl Shapiro (1990). "Horizontal mergers: an equilibrium analysis". In: *The American Economic Review*, pp. 107–126.

Friedman, James W (1971). "A non-cooperative equilibrium for supergames". In: *The Review of Economic Studies* 38.1, pp. 1–12.

Gelves, J Alejandro (2014). "Differentiation and cost asymmetry: Solving the merger paradox". In: *International Journal of the Economics of Business* 21.3, pp. 321–340.

Green, Edward J and Robert H Porter (1984). "Noncooperative collusion under imperfect price information". In: *Econometrica: Journal of the Econometric Society*, pp. 87–100.

Harrington Jr, Joseph E (2004). "Cartel pricing dynamics in the presence of an antitrust authority". In: *RAND Journal of Economics*, pp. 651–673.

Harris, Chris, Sam Howison, and Ronnie Sircar (2010). "Games with exhaustible resources". In: *SIAM Journal on Applied Mathematics* 70.7, pp. 2556–2581.

Hennessy, David A (2000). "Cournot oligopoly conditions under which any horizontal merger is profitable". In: *Review of Industrial Organization* 17.3, pp. 277–284.

Hsu, Judy and X Henry Wang (2010). "Horizontal mergers in a differentiated Cournot oligopoly". In: *Bulletin of Economic Research* 62.3, pp. 305–314.

Huck, Steffen, Kai A Konrad, and Wieland Müller (2001). "Big fish eat small fish: on merger in Stackelberg markets". In: *Economics Letters* 73.2, pp. 213–217.

Levenstein, Margaret C (1997). "Price wars and the stability of collusion: A study of the pre-world war I bromine industry". In: *The Journal of Industrial Economics* 45.2, pp. 117–137.

Levenstein, Margaret C and Valerie Y Suslow (2006). "What determines cartel success?" In: *Journal of economic literature* 44.1, pp. 43–95.

Mitchell, Jonathan F (2001). "Can a right of first refusal be assigned". In: *U. Chi. L. Rev.* 68, p. 985.

Mitraille, Sébastien and Michel Moreaux (2013). "Inventories and Endogenous Stackelberg Leadership in Two-Period Cournot Oligopoly". In: *Journal of Economics & Management Strategy* 22.4, pp. 852–874.

Montpelier, Dale J (1994). "Diamonds are Forever? Implications of United States Antitrust Statutes on international trade and the De Beers diamond cartel". In: *California Western International Law Journal* 24.2, p. 6.

Osborne, Dale K (1976). "Cartel problems". In: *The American Economic Review* 66.5, pp. 835–844.

Perry, Martin K and Robert H Porter (1985). "Oligopoly and the incentive for horizontal merger". In: *The American Economic Review* 75.1, pp. 219–227.

Porter, Robert H (1983). "Optimal cartel trigger price strategies". In: *Journal of Economic Theory* 29.2, pp. 313–338.

Rubinstein, Ariel (1982). "Perfect equilibrium in a bargaining model". In: *Econometrica: Journal of the Econometric Society*, pp. 97–109.

Salant, Stephen W, Sheldon Switzer, and Robert J Reynolds (1983). "Losses from horizontal merger: the effects of an exogenous change in industry structure on Cournot-Nash equilibrium". In: *The Quarterly Journal of Economics* 98.2, pp. 185–199.

Schmalensee, Richard (1981). "Economies of scale and barriers to entry". In: *Journal of Political Economy* 89.6, pp. 1228–1238.

Tirole, Jean (1988). *The theory of industrial organization*. MIT press.

Van Cayseele, Patrick and Dave Furth (1996). "Bertrand-Edgeworth duopoly with buyouts or first refusal contracts". In: *Games and Economic Behavior* 16.2, pp. 153–180.

— (2001). "Two is not too many for monopoly". In: *Journal of Economics* 74.3, pp. 231–258.

Velasco, Julian (2003). "Just do it: An antidote to the poison pill". In: *Emory LJ* 52, p. 849.

Vickers, John (2005). "Abuse of market power". In: *The Economic Journal* 115.504, F244–F261.

Wakui, Masako and Thomas K Cheng (2015). "Regulating abuse of superior bargaining position under the Japanese competition law: an anomaly or a necessity?" In: *Journal of Antitrust Enforcement* 3.2, pp. 302–333.

Walker, David I (1999). "Rethinking rights of first refusal". In: *Stan. JL Bus. & Fin.* 5, p. 1.

4

Detecting excessive pricing within a bargaining framework

This chapter was co-authored with Patrick Van Cayseele.

4.1 Introduction

A growing number of jurisdictions, particularly in Europe and Asia, have adopted provisions which prohibit the imposition of excessive prices in a business-to-business setting. Despite of this, none have so far been able to provide a definitive answer to the central question underlying these provisions: when are prices excessive?

As an example, Article 102 TFEU prohibits abuses of dominance, including the imposition of unfair prices. Yet it provides no clear guidance on what can be considered unfair.[1] The absence of objective criteria has sparked a lively debate in the literature, see for instance Lang and O'Donoghue (2002), Evans and Padilla (2005) or Akman and Garrod (2011). However, this lack of clarity has also led to limited enforcement efforts (Jenny, 2018). In this chapter, we therefore present a method to detect excessive pricing. Specifically, we propose the use of dictatorial outcomes within a Nash (1950) bargaining game as a benchmark against which to compare alleged excessive prices.

Excessive pricing is typically defined as a violation in which a "firm charges a price that is excessive relative to an appropriate competitive benchmark in a way that deems it unfair".[2] Any methodology designed to detect whether prices are excessive must therefore first establish a clear notion of what can be deemed fair. To do so, we rely on the 'no economic sense' criterion introduced by Werden (2005), who argues that conduct should be prohibited if it "would make no economic sense for the defendant but for the tendency to eliminate or lessen competition." We show how this criterion finds conceptual roots in the Nash (1950) cooperative bargaining model, which has recently seen use in a number of high profile antitrust cases (J. D. Wright and Yun, 2019).

We model the price at which an upstream supplier sells its output to a downstream buyer as the outcome of a two-player bargaining game with asymmetric bargaining power. In this setting, the dictatorial solutions of either party provide an upper and lower bound on what can be considered fair, as they are the outcome of negotiations should one party hold all the bargaining power. Once prices exceed these bounds,

[1] In *United Brands CO. v. Commission of the European Communities*, the EU Court of Justice advocated for an economics-based approach, as they considered prices to be unjust if they had no reasonable relation to the economic value of the product. According to the judgment, this could be shown by demonstrating both the existence of an *excessive* profit margin and that the price charged was *unfair* in itself or compared to competing products (Akman and Garrod, 2011). Although this type of comparative approach has become the norm, the question remains: what is excessive, and what is unfair?

[2] Gilon D., Excess prices, Global Dictionary of Competition Law, Concurrences, Art. N° 85402

this raises a clear red flag. When contracts implement outcomes that go beyond what a party with absolute bargaining power would obtain, that party must be pursuing a goal that goes further than what can be rationalized economically. In turn, this suggests the presence of abusive conduct based on the no economic sense criterion.

Such an approach avoids the often heard criticism that prohibitions of this type are inconsistent with the principles underlying competition law, as firms exercising their bargaining advantage is considered fundamental to thriving competition. This point of view is maintained by US antitrust enforcement, as reflected by the *Trinko* judgment, in which the Supreme Court argued that "the opportunity to charge monopoly prices is what attracts business acumen in the first place; it induces risk taking that produces innovation and economic growth".[3]

When assessing alleged excessive pricing, it is therefore crucial to distinguish between abusive conduct and competition on the merits (Vickers, 2005). The latter refers to behavior that produces outcomes similar to those arising from predatory conduct but cannot be considered unlawful. For example, inefficient firms exiting a market can be considered a desirable outcome, although these firms might argue that the terms they obtained were unfair and set with exclusionary or exploitative intent.

Consequently, regulators are forced to walk a tightrope, as both excessive prices and over-enforcement are assumed to stifle competition. For a more elaborate discussion on this issue, see Ezrachi and Gilo (2009). The proposed approach accommodates these concerns, as it allows for firms to exercise their bargaining advantage to the fullest. As a result, it accepts the reality that firms can find themselves in a weak bargaining position, and considers the fair price to be the one that would be charged to a firm facing a similar situation.

As an empirical application, we investigate an alleged case of excessive pricing on the European zinc market involving Belgian zinc smelter Nyrstar - at the time the world's largest smelter - and commodity trader Trafigura, as documented by Ying et al. (2021). Following a run of poor investments, Nyrstar found itself in severe financial difficulties in the mid-2010s. According to Nyrstar minority shareholders, Trafigura exploited this weakened position by taking a position of control in exchange for desperately needed cash injections, after which they engaged in increasingly lopsided deals with Nyrstar, further squeezing its margins. Allegedly, this was done with the intent of pushing Nyrstar into insolvency, allowing Trafigura to acquire all

[3]See Verizon Communications V. Trinko.

of its assets in a debt-for-equity exchange. In particular, it was claimed that the price Trafigura charged Nyrstar for providing the smelter with zinc concentrate was excessive.

Following the earlier discussed approach, price negotiations between zinc smelters and zinc concentrate suppliers are modelled as a cooperative bargaining game. Using publicly available data, we relate annual negotiated prices to unobserved bargaining power within a MIDAS (MIxed DAta Sampling) regression model (Ghysels, Santa-Clara, et al., 2004), using spot market prices as a proxy for bargaining power. Doing so allows us to identify the dictatorial solution of concentrate suppliers. We find that the price Trafigura charged to Nyrstar exceeded the estimated dictatorial solution of the former, suggesting a lack of economic sense. We link the upper bound on the negotiated price to work by Crespi et al. (2012) and Mérel and Sexton (2017), who argue that in vertical supply chains, it is often the case that there is a limit on the degree to which suppliers will squeeze the margins of their downstream partners, as subsequent exits could hurt their own margins in the long-run. Using anecdotal evidence from trade journals, we illustrate that similar dynamics were at play in the zinc supply chain.

The rest of this chapter is structured as follows. In section 4.2, we discuss the bargaining cycle on the zinc market, after which section 4.3 summarizes the dealings between Nyrstar and Trafigura. Section 4.4 develops the theoretical bargaining framework, after which section 4.5 provides an empirical analysis and discussion of the results. Section 4.6 concludes.

4.2 The market

The zinc market offers an ideal setting to study bargaining power, as it is characterized by a well-documented and predictable bargaining cycle between zinc smelters and miners. In addition to this, the market is quite transparent as there exist a number of trade journals, such as the Fastmarkets Metal Bulletin, which provide insights on current and expected market trends.

A key concept within the industry is profit sharing, as both zinc concentrate (zinc containing ores which have gone through an enrichment process) and processed zinc metal are sold at the same price. The profit made by either party therefore depends on the discount miners offer to smelters, which in turn depends on bargaining power along the supply chain. The zinc industry can be considered a good example of a bilateral oligopoly, in which a supply chain is characterized by a small number

of large firms, both upstream and downstream. In turn, this allows both sides to exercise some degree of market power, sometimes referred to as countervailing market power. However, the balance of power does shift over time depending on the market situation, allowing one party to obtain better terms at the other's expense.

4.2.1 Price formation

The LME price The benchmark price used in transactions involving zinc is set by the London Metal Exchange (LME), which is a commodity market where metal contracts are traded on a spot and future basis. LME prices are determined on an exchange basis and therefore influenced by global demand and supply. If the zinc metal supply decreases relative to demand, the LME price increases, and vice versa.

Treatment charges Both the price of concentrates and zinc metal are set in reference to the LME price, meaning it does not tell us much about a smelter's margins. In order to remain profitable, a smelter requires both a reduction on the LME price it pays for concentrate and a premium on top of the LME price it receives for zinc metal. On the input side, the most important factor is the treatment charge (TC), which is a fee negotiated between suppliers and smelters when purchasing metal concentrates. When a smelter buys concentrate from a miner, the TC is a rebate from the LME price. These TCs are set in reference to an annual benchmark, which is negotiated between major producers.[4]

Free metal On top of this rebate, a smelter only pays for 85% of the metal contained in zinc concentrates, with the remaining fraction denoted as free metal. In general, when a smelter buys a certain amount of zinc concentrate, he pays for the metal contained in this concentrate, the amount of which is given by the zinc grade. For instance, if a metric ton of concentrate is purchased with a zinc grade of 56%, this transaction involves 560kg of zinc metal. However, due to free metal, the smelter only pays for 456kg.

Premiums and by-products On the output side, margins are influenced by premiums which are payed on top of the LME price for commodity-grade zinc. The size of these premiums depend on the demand for specific products, e.g. specialised

[4]This TC is subject to both escalators (a percentage increase for each USD price increase above the base LME at which the initial benchmark was set) and de-escalators (a percentage decrease for price decreases below the base LME price).

Table 4.1: The bargaining cycle.
Source: Nyrstar.

Stage 1	Surplus in metal and concentrates; LME price decreases. Mines reduce output.
Stage 2	Concentrate supply decreases, bargaining power shifts to miners; TCs decrease. Smelters reduce output.
Stage 3	Metal supply decreases; LME price increases. Mine output increases.
Stage 4	Surplus in concentrates, bargaining power shifts to smelters; TCs increase. Smelter output increases.
Stage 1	Surplus in metal and concentrates; LME price decreases. ...

alloys for galvanizing. In addition to this, by-product sales are the revenues obtained by selling other metals contained in zinc concentrates which are recovered by the smelter, such as silver, gold and other precious metals.

4.2.2 The zinc cycle

The gross profit Π of a smelter s and a miner m at time t can be written in a stylized manner as

$$\Pi_{st} = q_t\Big(\rho(\bar{p}_t + \kappa_t) - (1-\phi)\bar{p}_t + \theta_t\Big), \tag{4.1}$$

$$\Pi_{mt} = q_t((1-\phi)\bar{p}_t - \theta_t), \tag{4.2}$$

with q_t denoting metric tons of zinc-in-concentrates. Smelter revenue equals the amount of zinc recovered from concentrates - which is given by the recovery rate ρ times the amount of zinc-in-concentrates processed - multiplied by the LME price $\bar{p}$ plus a premium κ. Material input expenditure is determined by the price of raw materials payed for (excluding free metal, the fraction of which is given by the parameter ϕ) minus a TC θ. For a miner m, gross profits equal the amount of payable metal multiplied by the LME price, minus the TC.[5]

Equations (4.1) and (4.2) illustrate that the gross margins of both smelters and miners are determined by two shared elements ($\bar{p}$ and θ), the magnitude of which is in turn determined by two sequential commodity markets: zinc concentrate and zinc metal.[6] The interplay between both largely determines the profitability of both

[5] See for instance Boliden annual report, 2020, p. 12 for more information of the income model of miners and smelters.

[6] Equation (4.1) also shows that the LME price on its own does not say much about the margins of

parties. When the supply of zinc concentrate is low relative to demand, the LME price increases but TCs drop as smelters have to compete harder for the available raw materials. Conversely, when supply is high, the LME price drops but TCs increase as bottlenecks are created due to insufficient smelting capacity. Table 4.1 gives an overview of the standard bargaining cycle in the zinc industry. The supply and demand dynamics which underlie the bargaining process within the zinc market closely resemble those in markets characterized by a delayed response in quantity to prices.[7]

As an example, consider figure 4.1 which depicts the monthly LME price as well as the benchmark TC. In 2015, LME prices began to drop as metal supply outpaced demand (stage 1). In turn, Glencore, one of the major producers of zinc concentrate, started to face an increasingly untenable situation as low LME prices coupled with high TCs saw its debt-to-ebitda ratio increase from 2.74 in 2012 to 4.74 in 2015. In order to stem the tide, it announced that it would stop all operations at one of its mines, and reduce output in others (Gilbert, 2021).[8]

Coupled with the announced shutdown of another mine (the Century Mine in Australia) this resulted in the market seeing its largest deficit ever, see figure 4.2.[9] This switch from surplus to deficit resulted in a marked change in bargaining power between smelters and miners and increasingly lower TCs from 2016 onwards (stage 2). As the deficit reached its lowest point, so did the negotiated benchmark TC.

However, at the same time, higher LME prices encouraged a higher mine supply (stage 3), which caused the market to switch from deficit to surplus mid-2018. This resulted in smelter bottlenecks and a higher TC (stage 4) as mine supply overwhelmed smelting capacity. Miners stated that as long as the LME price held, it "would not force them to close". However, once LME prices fall to a sufficient degree, the cycle restarts. Tellingly, in response to the 2019 negotiated benchmark TC, one

individual smelters. Differentiating with respect to $\bar{p}$ and θ respectively yields

$$\frac{\partial \Pi_{st}}{\partial \bar{p}_t} = q_t(\rho + \phi - 1) \quad \text{and} \quad \frac{\partial \Pi_{st}}{\partial \theta_t} = q_t. \tag{4.3}$$

Looking at the average recovery rate for zinc smelters and the percentage of free zinc metal - meaning $\rho = 0.96$ and $\phi = 0.15$ - it is easily seen that any increase in profits due to a change in the zinc benchmark price can be offset if it is accompanied by a decrease in the TC a fraction of its size. In the case of Nyrstar, it was reported that 49% of its gross profits came from TCs (Ying et al., 2021).

[7] Examples include agricultural products where past prices determine crop selection and hence future supply or high-school students deciding on their major based on the market conditions of recent graduates.

[8] The mines in question were the Lady Loretta mine in Queensland Australia, which stopped operations, and the McArthur river mine (Peru) and some smaller operation in Khazakstan

[9] Source: Statista

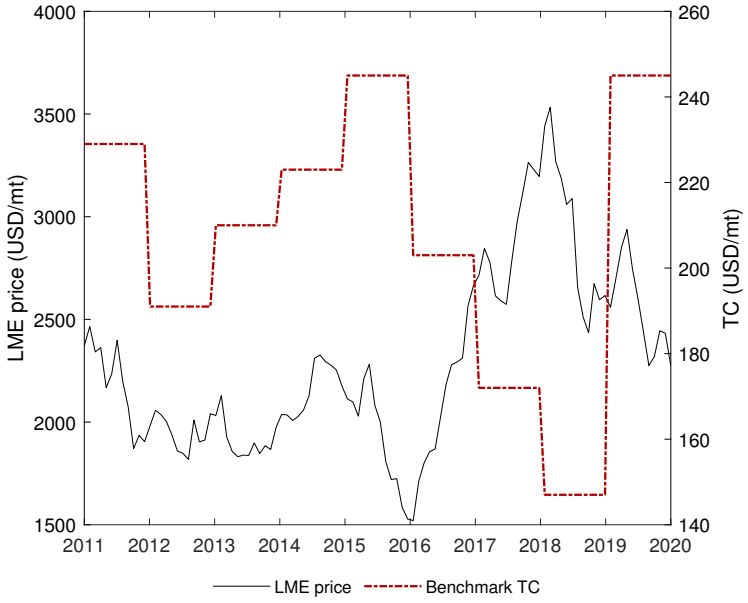
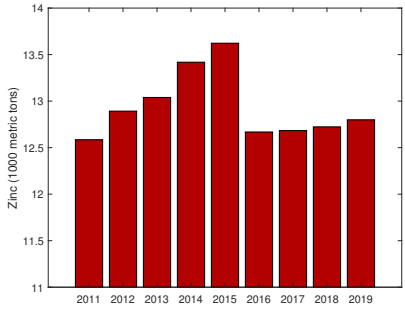
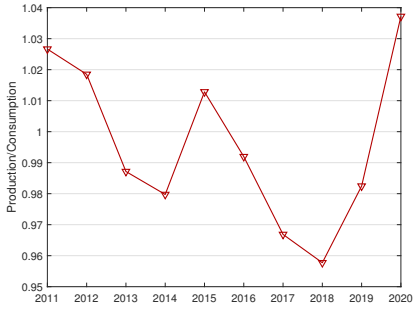


Figure 4.1: Price formation in the zinc industry.
Source: Bloomberg, Westmetal.



(a) Global zinc mine production.



(b) Global zinc production/consumption.

Figure 4.2: Zinc market deficit.
Source: Statista.

miner said that their margins were suffering, but "these thing come in cycles".[10]

4.3 The case

Having established an understanding of bargaining in the zinc supply chain, this section gives a brief summary of the events leading up to the deals between Nyrstar and Trafigura, after which both the content and aftermath of these deals are discussed.

Table 4.2: Zinc metal and zinc concentrate market shares.
Source: DG Comp.

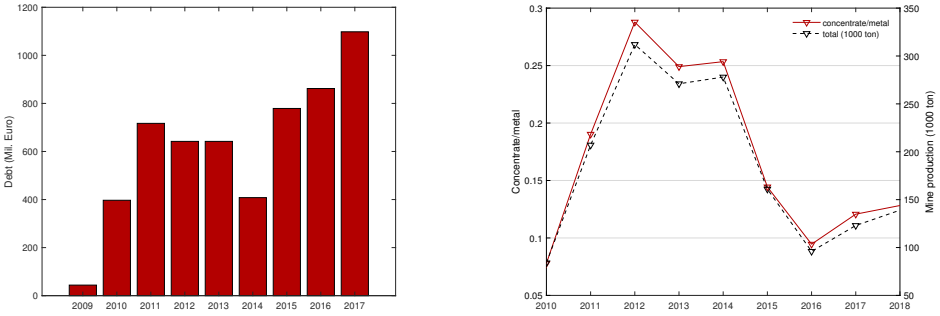
	Zinc metal		Zinc concentrate supply	
	EEA production	EEA supply	Worldwide	Excluding China
Glencore	5-10	20-30	10-20	20-30
Xstrata	20-30	10-20	0-5	5-10
Combined	30-40	40-50	10-20	20-30

The Merger In 2012, a merger agreement was reached between commodities trader Glencore and mining company Xstrata, with the former committing to buy the latter. The acquisition would make Glencore, already the world's largest commodity trader, one of the most important producers of natural resources and the largest zinc miner in the world (Blas and Farchy, 2021). According to the EC, the proposed merger jeopardized competition on the EEA market for finished zinc metal. Combined, the merging parties would supply 40-50% of all finished zinc (see table 4.2).

Under the EC's merger regulation, if a concentration causes concerns due to the creation (or strengthening) of a position of dominance, the merging parties are allowed to modify the merger in order to resolve these concerns.[11] For an overview of the ECs remedy policy, see Motta et al. (2007). The most important elements of the proposed remedy consisted of the divestiture of Glencore's 7.79% share in Nyrstar and a commitment not to purchase any zinc metal produced by Nyrstar in the EEA for a period of 10 years. The latter clause was motivated by the fact that Glencore had an offtake agreement with Nyrstar for selling its finished zinc, giving

[10] Daly, T. (2019, October 17). "Zinc treatment, refining charges seen high on rising mine supply", Reuters commodities news.

[11] See the Commission notice on remedies acceptable under Council Regulation (EC) No 139/2004 and under Commission Regulation (EC) No 802/2004.



(a) Nyrstar net debt.

(b) Nyrstar mine production.

Figure 4.3: Nyrstar's mining investments.
Source: Nyrstar annual reports.

it a (dominant) share of the total EEA supply. Without this offtake, Glencore's share would be reduced to its own production. Such a restriction was deemed not to be harmful to Nyrstar, as the EC's market test demonstrated strong interest in Nyrstar's zinc metal output.[12]

Nyrstar's mines The EC approved Glencore's acquisition of Xstrata under the conditions contained in the remedy proposal, thereby imposing a 10-year ban on trading between Nyrstar and Glencore. A large fraction of Nyrstar's zinc output, previously sold by Glencore, would be sold via Noble group under a new four year offtake agreement starting in 2014.[13]

Not long after the merger, Nyrstar became confronted with multiple problems. Noble faced significant financial troubles as it became embroiled in an accounting fraud affair. However, the bigger issue was Nyrstar's zinc concentrate supply, which is essential to the proper functioning of a smelter. In the Glencore-Xstrata merger proceedings, the EC had stated that Nyrstar possessed a reliable supply of zinc concentrate due to its successful vertical integration strategy.[14]

This statement would turn out to be incorrect. One of Nyrstar's most important sources of concentrate, the Century Mine in Australia, closed in 2015. In order to mitigate this loss, Nyrstar had indeed acquired a number of mines with the intent of

[12] See Case No COMP/M.6541 - GLENCORE / XSTRATA, p. 20-21.
[13] Under which Nyrstar received market price plus a benchmark premium per tonne of zinc metal, with a profit sharing mechanism for any upside.
[14] See Case No COMP/M.6541 - GLENCORE / XSTRATA, p. 98.

vertical integration. As a result, its debt had increased rapidly from 2009 onwards, as shown on figure 4.3a. However, some of these mines underperformed and had to be sold at a loss, with Nyrstar writing off €200 million of impaired assets in 2014 and a further €400 million in 2015.[15] This underperformance is reflected in the decreased mine output depicted on figure 4.3b, which also shows that Nyrstar became increasingly dependent on purchased concentrate to keep its output at a steady level, as illustrated by the decreasing ratio of zinc concentrate mined to metal produced (concentrate/metal). [16]

Trafigura In order to reduce its debt load and satisfy its concentrate needs, Nyrstar required liquidity. This liquidity could be provided by a long-term sales partner through prepayment. Enter Trafigura, one of the world's leading commodity traders specialising in oil, metals and minerals. It is perhaps most notorious for a 2006 toxic waste scandal in Côte d'Ivoire (Blas and Farchy, 2021).

For over a decade, Trafigura had attempted to close a zinc offtake deal with Europe's top smelter only to lose out to its chief competitor Glencore in 2008 and to Noble in 2013. Thanks to adverse conditions and the remedy imposed by the EC, an opportunity now presented itself.[17] As also mentioned in chapter 3, in a 2020

[15] Burton, M. (2018, November 13). "How a Mountain of Debt Brought a Top Zinc Producer to the Brink", Bloomberg.

[16] Looking at annual data on the output of zinc mines, there was indeed a decrease from 13.3 million metric tons in 2014 to 12.8 million in 2015 and further to 12.5 million in 2016. Gilbert (2021) argues that these output cuts highlight the sometimes misguided emphasis antitrust authorities place on market shares when assessing competition. Although it produced only 16.4% of total zinc mine output, the low short-term production and consumption elasticities characteristic of the metal market allowed Glencore's output to have a large effect on the zinc price.

Often used measures of concentration, like the Hirschman-Herfindahl index (HHI) and C4 ratio, were relatively low in the zinc concentrate sector, with HHI=0.0601 and C4=42.9%. Antitrust authorities employ these indices as a guideline in order to assess market power. The Lerner index (L) is an important metric of market power, which measures the percentage markup a firm can make over its marginal cost such that

$$\mathrm{L} = \frac{p - c}{p}. \tag{4.4}$$

Given a symmetric Cournot oligopoly model, there is a straightforward relationship between concentration, the price elasticity of demand η and the Lerner index, as

$$\mathrm{L} = \frac{\mathrm{HHI}}{\eta}, \quad \text{with} \quad \eta = \frac{\partial \ln(q)}{\partial \ln(p)}, \tag{4.5}$$

which implies that market power increases as concentration increases. However, market power also increases as demand becomes less elastic. Hence, both aspects need to be considered when assessing mergers. As demand elasticity varies across industries, targetting a specific level of concentration is misguided.

[17] See Farchy, J. (2012, November 1). "Glencore's rivals salivate over antitrust offer", Financial Times.

general meeting of Nyrstar shareholders, the Nyrstar board of directors had put it as follows:

> "The combination of supplying concentrate, providing the zinc metal offtake with prepayment terms [...] there were not a lot of players in the market who could do that. Maybe Glencore could, but they had the European Commission decision."[18]

They further stated that:

> "[...] Trafigura came out as the only realistic option that could provide the security of supply and offtake Nyrstar needed in terms of quantity and quality in the longer term as well as other terms that smelters commonly seek such as prepayment."[19]

In an attempt to reduce its debt load, Nyrstar had launched a rights issue in 2014 and again in 2015, which led to Trafigura acquiring a 20.02% stake by 2015. The EC warned that - based on the historical attendance rates at Nyrstar shareholder meetings - this gave Trafigura a high likelihood of controlling a stable majority of the votes at Nyrstar shareholder meetings, giving it *de facto* sole control of Nyrstar.[20]

By 2015, Nyrstar had appointed two Trafigura nominees to the board, although shareholders had raised objections about their capacity to act independently.[21] By 2016, three out of six members, including the chairman, were Trafigura nominees. In addition to this, Nyrstar and Trafigura agreed to a number of deals which are depicted on figure 4.4 and were supposedly set at arm's length, including:

(i) An agreement to provide Nyrstar with zinc concentrate accounting for one third of its total requirements.[22]

(ii) A right of first refusal on certain Nyrstar metal volumes.[23]

[18] See Written questions for annual general meeting and extraordinary general meeting to be held on 30 June 2020 , p. 3.

[19] Ibid. p. 3.

[20] According to the European Commission, "[a] minority shareholder may also be deemed to have sole control on a de facto basis. [...] Where, on the basis of its shareholding, the historic voting pattern at the shareholders' meeting and the position of other shareholders, a minority shareholder is likely to have a stable majority of the votes at the shareholders' meeting, then that large minority shareholder is taken to have sole control." See Case M.7779 - TRAFIGURA / NYRSTAR.

[21] Trafigura increases stake in Nyrstar to 20%

[22] Approximately 550.000, 499.000 and 498.000 tons of zinc concentrate between 2016-2018.

[23] A right of first refusal is a contractual agreement which obliges Nyrstar to offer its output to Trafigura. Only after a 'first refusal' by Trafigura can output be offered to a third party. See Van Cayseele and Furth (1996).

(iii) Multiple zinc offtake agreements in which Trafigura purchased finished metal from Nyrstar, eventually amounting to its entire output. Based on 2014 market shares (see appendix C.1) this would amount to Trafigura supplying 35-40% of the EEA market.

Nyrstar minority shareholders claimed that these deals were set at terms highly favorable to Trafigura, and that the significant discounts awarded resulted in a loss of €200 million in gross profit over the period 2016-2018, accounting for one third of Nyrstar's total gross profits.[24] They further questioned the loyalty of the Nyrstar board members nominated by Trafigura, likening them to Manchurian candidates who had engaged in these deals with the sole intention of creating (or exacerbating) a liquidity crisis. In this sense, the alleged tactic employed by Trafigura can be related to the concept of tunneling, see Johnson et al. (2000), which refers to majority shareholders using their influence over a company to transfer resources from that company to themselves. Moreover, the agreements were made for a fixed term of five years after which Trafigura could unilaterally terminate the deal but Nyrstar could not unless Trafigura's shareholding in Nyrstar fell below 20%.[25]

As shown on figure 4.4, Nyrstar's market value had been on a downward trajectory since 2011. By 2018, its liquidity constraints had cast serious doubts on the smelter's ability to refinance €340 million in outstanding bonds.[26] A damning report by Dutch bank ABN AMRO - calling the company virtually worthless and advising investors to abandon ship - resulted in a final crash in the share price mid-2018.[27] With bond refinancing out of the question due to the high yield-to-maturity rate on outstanding bonds, the remaining option was debt re-structuring. This took the

[24] Dendooven, P. (2019, December 21). "Strijd tegen redder of raider?, De Standaard.

[25] For information on the relationship agreement, see Nyrstar 2017 annual report, p. 189. Dendooven, P. (2019, December 21). "Strijd tegen redder of raider?", De Standaard, and Hoffman, A. & Burton, M. (2019, September 8). "Trafigura Accused of Throttling Nyrstar With Lopsided Deals", Bloomberg.

It is also interesting to note that the Belgian legislator adopted a prohibition on unfair contracts, providing a blacklist of contractual terms which are deemed unfair without requiring further assessment (Dewispelaere and Binet, 2019). Agreements which create an irrevocable obligation for a contracting party while the obligations of the other party are subject to conditions which depend on the will of this other party, are considered to be unfair. This description fits the 2016 agreement between Trafigura and Nyrstar, which was set for a fixed five year term after which Trafigura could renew it for another five years. Afterwards, it was expected to continue on an evergreen basis unless Trafigura terminated it. Nyrstar, however, could not terminate the deal as long as Trafigura maintained a stake in Nyrstar above 20%. See Nyrstar 2016 annual report, p. 168.

[26] Hoffman, A. & Farchy, J. (2018, October 25). "Trafigura's Bold Bet on Zinc-Maker Nyrstar Is Getting Uglier", Bloomberg.

[27] Controversially, Goldman Sachs released their own analysis one day later, predicting a Nyrstar share-price movement from €4.5 to €7.5 in the coming months.

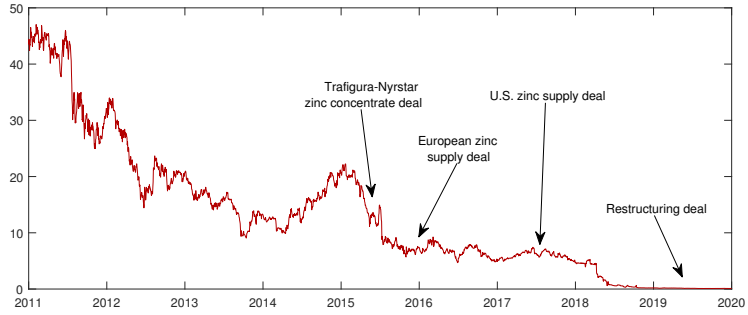


Figure 4.4: Nyrstar N.V. daily Euronext stock quote (€).
Source: Thomson Reuters.

form of a debt-for-equity exchange, which saw Trafigura take over virtually all of Nyrstar's operations at the symbolic price of €1.[28]

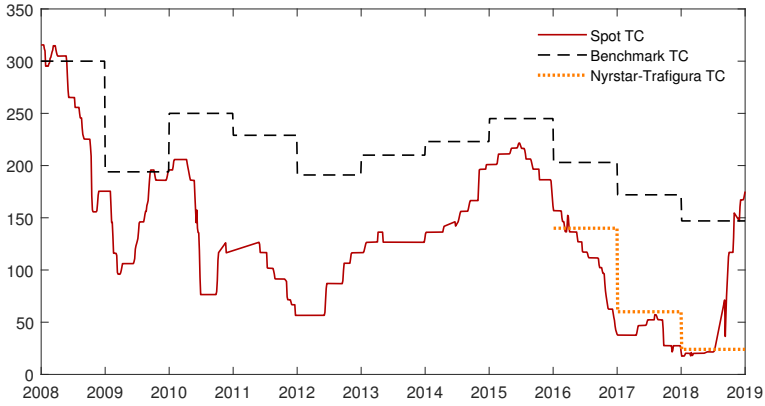


Figure 4.5: Treatment Charges (TCs) in USD/mt.
Source: Bloomberg, Eikon Refinitiv Datastream.

[28] Hume, N. (2018, 12 November). "Nyrstar shares crash as analysts tell investors to "abandon ship"", Financial Times; It has been alledged that Trafigura in fact accelerated this crash by threatening to block Nyrstar from drawing on a €250 million loan facility, which led Nyrstar to exclude this facility as part of its liquidity. As the final crash resulted from Nyrstar's inability to refinance its debt due to liquidity constraints, blocking key credit would certainly have contributed, see Hoffman et al. (2020, november 6). "Trafigura Threatened to Deny Nyrstar Key Credit, Adviser Says"", Bloomberg.

Table 4.3: Nyrstar's typical mix of TC terms.
Source: Nyrstar.

TC terms	Feed share	Escalator
Benchmark TC with mines	30-40%	Full
Benchmark TC with discount, primarily traders	50-60%	Predominantly
Spot market	5-10%	Generally not

The deals Although it is said that Trafigura received a significant discount on the price it paid for finished metal, the specifics of these contracts are unknown.[29] Instead, we focus on the upstream deals for zinc concentrate and the TCs negotiated between Nyrstar and Trafigura, which are depicted on figure 4.5, alongside the benchmark and spot market TC. It can be seen that the TCs are far below the benchmark and much closer to the spot level.

There exists a spot market for zinc concentrates, which is relatively illiquid and constitutes on average 10% of all concentrates. Normally speaking, Nyrstar uses benchmark TCs as a basis for determining the TCs paid to long-term suppliers, while spot TCs are used for short-term surpluses or deficits, sometimes being referred to as a market of last resort. Table 4.3 depicts a typical composition of Nyrstar's TC terms as reported in 2017. Purchases are predominantly made at either benchmark terms with other mines or at a discount to the benchmark with traders. In 2017, Nyrstar reported that on average TCs were set $10-30 below the benchmark and in 2018 they re-stated that only 5-10% of their concentrate feed was purchased at spot terms.

When asked about the terms negotiated with Trafigura, the Nyrstar board stated that "traders, such as Trafigura, did not price contracts at benchmark terms but nearer spot terms."[30] While it is true that traders do not operate at benchmark terms, they generally set their price in reference to the benchmark with discounts applied. Yet in terms of costs there was no difference between zinc purchased on the spot market or under a long-term deal with Trafigura (with the exception of 2018, when spot terms were far more favourable).

As previously mentioned, if firms are unable to turn a profit, this does not indicate the presence of abusive conduct. The next section therefore develops a

[29] Hoffman, A. & Burton, M. (2019, September 8). "Trafigura Accused of Throttling Nyrstar With Lopsided Deals", Bloomberg.
[30] see Written questions for annual general meeting and extraordinary general meeting to be held on 30 June 2020, p. 3.

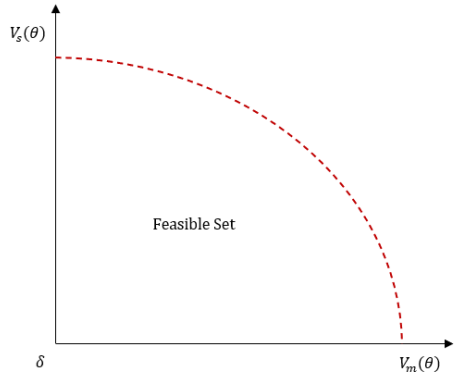


Figure 4.6: The Bargaining Problem.

theoretical framework which allows for the derivation of a benchmark price, which provides an upper bound on what can be considered fair terms.

4.4 Theoretical framework

In this section, we employ a simple two-player bargaining framework as formulated by Nash (1950) and Nash (1953) to model profit sharing within a vertical supply chain.[31] This framework is used to analyse the outcome of benchmark TC negotiations between smelters and miners.

4.4.1 The bargaining model

The bargaining environment is characterized by (i) a feasible set of outcomes, (ii) a disagreement point δ and (iii) the payoff functions of either player. Following the literature, it is assumed that the set of outcomes is convex, closed and bounded and contains at least one point in which strictly dominates δ (Thomson, 1994). Furthermore, it is assumed that both players possess complete information. Denote the respective payoffs of smelters and miners as

$$V_{st}(\theta_t) \quad \text{and} \quad V_{mt}(\theta_t), \tag{4.6}$$

[31] The approach we employ consists of measuring a parameter α on the unit interval, which governs the relative share of a 'surplus' received by either side. Alternatively, a structural IO framework in the style of Bresnahan (1989) can be employed, as it is possible to formulate a model of bilateral oligopoly in which bargaining power on either side of the supply chain is measured by a pair of conduct parameters, see Schroeter et al. (2000).

with θ_t denoting the negotiated TC.

In the literature, the disagreement point has been interpreted in various ways, including as either players' threat point (Brito et al., 1977) or the status quo ante (Binmore et al., 1986). As the disagreement point provides a boundary for the feasible set, we denote it as

$$\delta_t = \Big(V_{mt}(\underline{\theta}_t + \bar{\theta}_t), V_{st}(\underline{\theta}_t)\Big) \tag{4.7}$$

$$= (\delta_{mt}, \delta_{st}), \tag{4.8}$$

meaning

$$\theta_t \in [\underline{\theta}_t, \underline{\theta}_t + \bar{\theta}_t]. \tag{4.9}$$

Fig 4.6 provides a graphical example of the bargaining problem. As miners prefer a low TC, their disagreement payoff provides an upper bound on the negotiated TC. Similarly, the disagreement payoff of the smelter provides a lower bound. It is therefore further assumed that

$$V'_{st}(\theta_t) > 0 \quad \forall \theta_t \in [\underline{\theta}_t, \underline{\theta}_t + \bar{\theta}_t), \tag{4.10}$$

$$V'_{mt}(\theta_t) < 0 \quad \forall \theta_t \in (\underline{\theta}_t, \underline{\theta}_t + \bar{\theta}_t]. \tag{4.11}$$

4.4.2 The Nash solution

It is assumed that the outcome of annual benchmark negotiations between smelters and miners is the Nash (1950) cooperative bargaining solution. This solution concept has been employed in various applications, including bargaining in bilateral oligopolies (Horn and Wolinsky, 1988) and wage negotiations between employers and workers (Cahuc et al., 2006). Moreover, it has seen use in a number of high profile antitrust cases, see J. D. Wright and Yun (2019). The Nash solution is part of the axiomatic approach to bargaining, as it proposes an outcome which satisfies a number of normative properties: symmetry, scale invariance, efficiency and independence of irrelevant alternatives.

As a result, this solution can be considered artificial. Moreover, other elements relevant to the bargaining process, such as risk contingencies, contract length, interaction frequency, etc. are not included within the model. Nonetheless, Binmore et al. (1986) show that the Nash solution is the limiting outcome to the Rubinstein (1982) non-cooperative strategic approach to bargaining , whereas under certain conditions Collard-Wexler et al. (2019) extend this generalization to strategic bargaining be-

tween multiple upstream and downstream firms. Mathematically, the Nash solution solves the following optimization problem

$$\begin{aligned} \theta_t = \quad & \arg\max_\theta \left\{ \Big(V_{st}(\theta) - \delta_{st}\Big)\Big(V_{mt}(\theta) - \delta_{mt}\Big) \right\} \\ \text{s.t.} \quad & \begin{cases} V_{st}(\theta) \geq \delta_{st}, \\ V_{mt}(\theta) \geq \delta_{mt}. \end{cases} \end{aligned} \tag{4.12}$$

In order to introduce bargaining power, the non-symmetric Nash solution is considered, which is the outcome to a bargaining problem in which asymmetries - representing relative bargaining power - are introduced using a weight $\alpha \in [0, 1]$. This weight determines the importance placed on either player's payoff and captures un-modelled bargaining effectiveness (Kalai, 1977).

The asymmetric Nash solution maximizes the following product

$$\begin{aligned} \theta_t = \quad & \arg\max_\theta \left\{ \Big(V_{st}(\theta_t) - \delta_{st}\Big)^{\alpha_t} \Big(V_{mt}(\theta) - \delta_{mt}\Big)^{1-\alpha_t} \right\} \\ \text{s.t.} \quad & \begin{cases} V_{st}(\theta) \geq \delta_{st}, \\ V_{mt}(\theta_t) \geq \delta_{mt}. \end{cases} \end{aligned} \tag{4.13}$$

Internalizing the constraints yields the following unconstrained optimization problem

$$\lambda_t = \underset{\lambda \in [0,1]}{\arg\max} \left\{ \Big(V_{st}(\underline{\theta}_t + \lambda\bar{\theta}_t) - \delta_{st}\Big)^{\alpha_t} \Big(V_{mt}(\underline{\theta}_t + \lambda\bar{\theta}_t) - \delta_{mt}\Big)^{1-\alpha_t} \right\}. \tag{4.14}$$

From (4.10), (4.11) and (4.14) it follows that

$$\lim_{\alpha_t \to 0} \theta_t = \underline{\theta}_t, \quad \text{and} \quad \lim_{\alpha_t \to 1} \theta_t = \underline{\theta}_t + \bar{\theta}_t. \tag{4.15}$$

Should bargaining power be skewed towards one party, she will be able to push the outcome further along the Pareto frontier, closer to the other party's disagreement solution, which is equivalent to its dictatorial solution.

Based on this theoretical framework, we attempt to identify the dictatorial solution of zinc miners, that is, the outcome which a miner would impose if she held all the bargaining power during negotiations. More specifically, variation in bargaining power over time is used to obtain an estimate of the expected value of $\underline{\theta}_t$ as the constant within a regression framework. Let $\tilde{\alpha}$ be an observed proxy variable

for unobserved bargaining power α such that

$$\lim_{\alpha_t \to 0} \tilde{\alpha}_t = 0, \tag{4.16}$$

which is used to specify the following n'th order polynomial regression

$$\theta_t = \sum_{k=0}^{n} \beta_k \tilde{\alpha}_t^k + \epsilon_t. \tag{4.17}$$

From (4.15) and (4.17) it follows that

$$\lim_{\alpha_t \to 0} \theta_t = \underline{\theta}_t, \tag{4.18}$$

$$\beta_0 = \mathrm{E}[\theta_t \mid \tilde{\alpha}_t = 0]. \tag{4.19}$$

From (4.16)-(4.18), it then follows that

$$\lim_{\tilde{\alpha}_t \to 0} \theta_t = \mathrm{E}[\theta_t \mid \alpha_t = 0] \tag{4.20}$$

$$= \mathrm{E}[\underline{\theta}_t] = \beta_0. \tag{4.21}$$

Bargaining power is fundamentally unobserved. However, based on Section 4.2, it is closely related to whether or not the zinc concentrate market is in deficit or surplus. In the next section, we propose using spot market TCs as a proxy of bargaining power, after which a MIDAS regression model is used to estimate $\mathrm{E}[\underline{\theta}_t]$, henceforth $\underline{\theta}$.

4.5 Empirical analysis

4.5.1 The data

The main data employed in this analysis consists of annual (negotiated) benchmark TCs and monthly spot market TCs between 2008 and 2020. The benchmark TCs are generally set in the first quarter of the year and announced in trade journals.[32] The spot TC is updated continuously, meaning observations are available at a daily frequency. As we do not have direct access to a historical database of spot TCs, the data employed in this analysis was reverse engineered using publicly available

[32]The data on benchmark TCs used in this analysis is provided by Bloomberg.

Table 4.4: Summary Statistics.

Variable	Obs.	Mean	Standard Deviation	Min.	Max.
Benchmark TC ($)	13	223.77	43.46	147	300
Spot TC ($)	156	146.09	77.45	20.18	315.77
Steel Price Index	156	220.71	24.92	168.9	294.4
LME Price ($)	156	2196.93	462.35	1100.57	3539.78
Δ stocks (mt)	156	-0.71	34.37	-116.10	85.75

images from Eikon's Refinitiv Datastream. The data was extracted using MATLAB 'GRABIT' and linear interpolation was used to create 365 data-points for each year worth of data. Taking the monthly mean provided reliable estimates for the monthly spot TC, as depicted on figure 4.5.

We further observe the monthly level of the LME price and the change (Δ) in zinc stocks held at the LME, which are publicly provided by Westmetall, a German non-ferrous metal trader. As zinc inventories become depleted once the market turns to a deficit, it could be presumed that changes in the stock level might be closely related to where bargaining power is situated along the supply chain. Lastly, we include the global index of steel prices in the analysis, which is publicly provided by the Federal Reserve's economic database. Inclusion is motivated by the fact that about 75% of all zinc is used in galvanization, meaning steel and zinc demand are closely related. Summary statistics are given in table 4.4.

4.5.2 Measuring bargaining power

As a baseline specification, bargaining power α is modelled as an additively separable function of its determinants, yielding the following estimating equation

$$\theta_t = \beta_0 + \beta_1 \theta_t^s + \beta_2 \bar{p}_t + \beta_3 \text{steel}_t + \beta_4 \Delta\text{stocks}_t + \epsilon_t. \tag{4.22}$$

This regression is used to examine annual benchmark TC negotiations, with the dependent variable θ_t being the monthly level of the benchmark TC. It should be noted that θ_t is observed annually, but enters (4.22) at a monthly frequency with repetitive information. All explanatory variables are observed at a monthly frequency. These include the monthly spot TC, denoted θ_t^s, the LME price $\bar{p}_t$, the steel price index and the change in the LME zinc stock in metric tons.

OLS estimates are reported in table 4.5. The signs on all significant coefficients conform to expectations. As expected, there is a positive relation between the spot

Table 4.5: OLS Estimation results.

Variable	(1)	(2)	(3)	(4)
Constant	168.12***	201.35***	162.91***	162.13***
	(4.89)	(13.92)	(22.69)	(22.58)
θ_t^s	0.38***	0.36***	0.36***	0.36***
	(0.03)	(0.04)	(0.03)	(0.03)
$\bar{p}_t$		-0.01***	-0.02***	-0.01***
		(0.01)	(0.01)	(0.01)
steel_t			0.19***	0.19**
			(0.08)	(0.08)
Δstocks_t				-0.08
				(0.06)
R-squared	0.46	0.48	0.49	0.50
Observations			156	

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, Robust standard errors in parentheses.

TC and the benchmark, which is consistent with the notion that the spot market reflects supply-demand dynamics on the zinc market, which in turn determines bargaining power.

The coefficient on the LME price is negative, which again is not surprising given the bargaining cycle and the timeframe considered. LME prices were relatively low for a long time as zinc concentrate supply outpaced demand, resulting in high TCs. Once mining output decreased in 2016, an increase in the LME price was accompanied by a decrease in TCs. This trend was reversed in 2019.

4.5.3 MIDAS regression

On its own, the spot TC is a relatively good predictor of the benchmark with an R-squared close to 0.5, and including more covariates only marginally increases the fit. This is to be expected. Fastmarkets (the main commodity price reporting agency) uses spot TCs as the basis for their forecasting models.[33] At any point in time the spot market gives a good indication of where bargaining power is situated, as it essentially reflects the current supply-demand (im)balance. In this sense, prices in the zinc market can be linked to directed search models (R. Wright et al., 2021), as negotiated prices between suppliers and buyers are linked to market tightness and the relative number of active buyers and sellers. As the spot price increases, this signals higher bargaining power on the supply side, implying better terms of trade for miners.

[33] See "International Zinc Association 2022 to focus on zinc smelters' output cuts" (2022, February 14). FASTMARKETS.

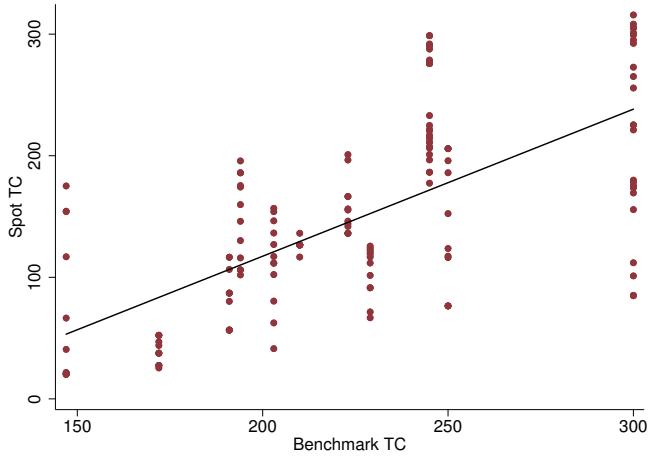


Figure 4.7: Spot TC vs. Benchmark TC (2008-2020).

However, Fastmarkets reports an R-squared of up to 0.93 in their forecasting models between the spot and benchmark TC, meaning the baseline model falls short in comparison. One main issue is that the dependent and independent variables are sampled at different intervals, see also Figure 4.7. Spot TCs are observed monthly, whereas benchmark TCs are set annually, meaning there is no between-month variation for any given year in the dependent variable. In order to circumvent this issue, a methodology proposed by Ghysels, Santa-Clara, et al. (2004) and Ghysels, Sinko, et al. (2007) is employed, called MIDAS regression (MIxed DAta Sampling).

When regressing high frequency on low frequency data, placing an individual coefficient on each high frequency observation can easily lead to over-fitting. Alternatively, aggreggating the higher frequency variable to a lower frequency results in a loss of information. In order to overcome these issues, MIDAS regression uses a parsimonious function which determines the coefficient on each observation, but is governed by a limited number of hyperparameters. Consider the following regression

$$\theta_j = \beta_0 + \beta_1 \sum_{m=1}^{12} \Phi(m, \omega)\theta^s_{mj} + \epsilon_j, \tag{4.23}$$

with the subscript j denoting the year and the subscript m denoting the month. The weighting function $\Phi(.)$ can take any number of functional forms. Ghysels,

Table 4.6: MIDAS estimation results.

	Pre-2019			**Full sample**		
Parameter	Beta	Almon exp.	OLS	Beta	Almon exp.	OLS
Constant	149.39	149.18	149.01***	154.00	149.78	150.58***
			(7.54)			(6.95)
β_1	0.49	0.49	0.49***	0.45	0.48	0.47***
			(0.04)			(0.03)
$\Phi(3,\omega)$	2e-03	1.35e-21	0	0.92	0.99	1
$\Phi(4,\omega)$	0.53	0.49	0.5	0.03	3.03e-09	0
$\Phi(5,\omega)$	0.46	0.51	0.5	9.53e-06	2.99e-117	0
R-squared			0.94			0.91
Obs.	11/132		11	13/156		13

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, Robust standard errors in parentheses.

Santa-Clara, et al. (2004) suggest a beta formulation

$$\Phi(m,\omega) = \frac{f(m,\omega)}{\sum_{k=1}^{12} f(k,\omega)}, \tag{4.24}$$

which is governed by a pair of parameters $\omega = \{\omega_1, \omega_2\}$, with

$$f(m,\omega) = (m/12)^{\omega_2 - 1}(1 - m/12)^{\omega_2 - 1}\mathbf{B}(\omega). \tag{4.25}$$

The beta function $\mathbf{B}(.)$ has the following form

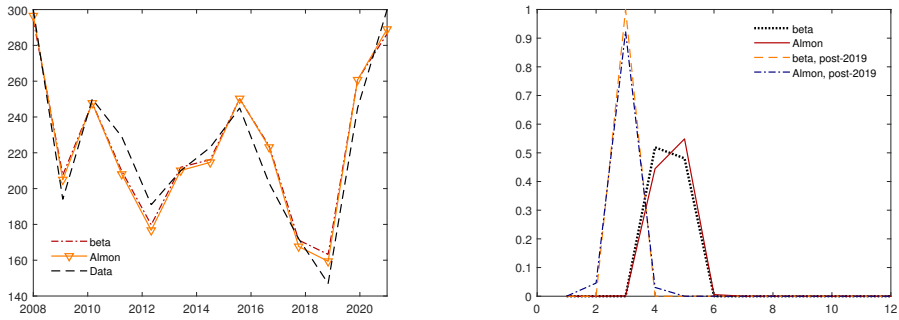
$$\mathbf{B}(\omega) = \frac{\Gamma(\omega_1 + \omega_2)}{\Gamma(\omega_1)\Gamma(\omega_2)}, \tag{4.26}$$

with

$$\Gamma(z) = \int_0^\infty \exp(-x)x^{z-1}dx. \tag{4.27}$$

Based on this functional specification, (4.23) can be estimated using non-linear least squares.

Regression estimates are reported in table 4.6. Using this type of methodology results in a weight being placed on observations in the end of the first and beginning of the second quarter of the year, as depicted on figure 4.8b. Running the regression for two functional forms (the earlier mentioned beta function and an exponential



(a) Model fit.

(b) Monthly weight, 1=January.

Figure 4.8: MIDAS regression.

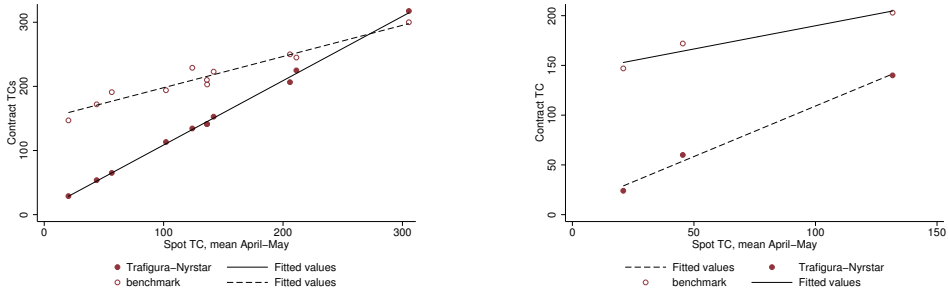
Almon[34] specification) yields an almost identical fit, see figure 4.8a. The regression is estimated using two different samples, one excluding observations after 2018 (as the Nyrstar-Trafigura deals did not continue after this date) and one including observations up until 2021.

Although the weights on each monthly observation differ somewhat depending on the sample size, this is not that much of an issue as spot TCs are generally not that volatile month-on-month. More interesting is the fact that the estimates are consistent with benchmark negotiations taking place in the first quarter of the year, and tending to conclude between March-April, after which the agreed TC is retroactively applied. It seems plausible that benchmark TCs would reflect spot TCs more closely at the time when negotiations are under way, as these are based on current demand-supply imbalances and are therefore assumed to reflect bargaining power at that point in time. In appendix C.2, an alternative approach is employed using interpolation, yielding a similar result. An additional advantage of the MIDAS approach within a bargaining framework is that it allows informed players in forward looking markets to place a weight on future spot TCs, as these could reflect their expectations of which way the market will turn. However, this seems not to be the case in our model.

As the slope parameter β_1 and the parameters governing the weighting function

[34]The Almon specification is also suggested by Ghysels, Sinko, et al. (2007), such that

$$\Phi(m, \omega_1, \omega_2) = \frac{\exp(\omega_1 m + \omega_2 m^2)}{\sum_{k=1}^{12} \exp(\omega_1 k + \omega_2 k^2)}. \tag{4.28}$$



(a) Benchmark fit and counterfactual.

(b) Model fit.

Figure 4.9: MIDAS fit.

are not separately identified, hypothesis testing is performed taking the estimates on ω as given. In both cases, using OLS and taking the (rounded) weights as given results in a good fit, with an R-squared close to what was reported by Fastmarkets in their models. In the case of the pre-2019 sample, this amounts to regressing the anual benchmark on the mean spot TC in the fourth and fifth month of that year. Similary, in the case of the full sample, anual benchmarks were regressed on the spot TC in the third month of each year, yielding an almost identical fit. In order to test the linear specification, (4.23) was re-estimated including quadratic terms, but the estimated coefficients did not significantly differ from zero.

4.5.4 A fair price?

Figure 4.9a plots the fit of the MIDAS model using the pre-2019 sample, meaning contractual terms are regressed on the average spot TC between April and May. Using a similar specification, we can model the TCs in the Nyrstar-Trafigura deal as a function of spot TCs. Doing so yields the fit as depicted on figure 4.9b. Parameter estimates also allow for the calculation of counterfactual terms, which are depicted on figure 4.9a as a point of comparison. The fitted lines are not parallel as the slope coefficient is almost equal to one in the case of the Nyrstar-Trafigura TCs. More interestingly, the intercept is close to zero.

Given the earlier specified MIDAS regression equation (4.23), it follows that

$$\beta_0 = \mathrm{E}[\theta_j \mid \theta_j^s = 0], \tag{4.29}$$

with $\theta_j^s = \{\theta_{1j}^s, ..., \theta_{12j}^s\}$. Moreover, as both bargaining power and the spot TC are

determined by supply and demand on the zinc market and the lower bound on the spot TC is zero, it can be assumed that

$$\lim_{\alpha_{mj} \to 0} \theta^s_{mj} = 0. \tag{4.30}$$

As a result, the constant from the MIDAS regressions can be interpreted as an estimate of the miners' profit-maximizing TC, such that $\beta_0 = \hat{\underline{\theta}}$. Following this interpretation, $\hat{\underline{\theta}}$ hovers around 150 USD. As a consequence, the price charged by Trafigura to Nyrstar far exceeded the benchmark in 2017 and 2018.

When interpreting this upper bound, it should be noted that in a horizontal setting, the exit of a competitor tends to benefit the remaining firms. This is not necessarily the case in a vertical setting as the one under consideration. Crespi et al. (2012) and Mérel and Sexton (2017) argue that actors on one side of a supply chain can benefit from short-run bargaining advantages to squeeze the margins of their counterparts. However, doing so to an excessive degree can result in increased exit or reduced entry. Should firms not sufficiently internalize these long-term consequences, short run exploitation of the 'stock' of suppliers or buyers can result in long-term exhaustion.

Although these concerns are not necessarily present in all supply chains, they are thought to be prevalent in sequentially interdependent chains, where downstream firms cannot function without upstream inputs and upstream firms cannot market their products to the consumer without downstream buyers (Crook and Combs, 2007). This description fits the zinc supply chain. Indeed, similar concerns were voiced, indicating that both miners and smelters placed a high value on expected profits, lessening their incentive to exercise buyer or seller power.

Miners and smelters are mutually dependent, as one side cannot operate without the other. As mentioned previously, miners know that low smelter profits and a subsequent lack of investment in smelting capacity could cause bottlenecks in the future, which hurts their expected margins. In 2017 (a seller's market), analysts warned that if miners insisted on low TC terms, a large number of smelters would stop operating, whereas during the 2018 benchmark negotiations the CEO of Glencore, the largest zinc concentrate producer, noted that "treatment and refining charges are getting tight, smelters are finding it though. I think a balance has to come because we're going to need the smelters to survive".[35] Similarly, smelters require sufficiently

[35] Hotter, A. (2017, February 28) "Hotter on metals: Zinc miners, smelters brace for TCs talks", Metal Bulletin.

high mining capacity, as they do not want to see a concentrate market in deficit, resulting in low TCs.

When interpreting the disagreement point as the status quo ante or threat point, it is assumed that either player would prefer walking away from the negotiating table over accepting terms worse than the their payoff in the disagreement point. However, it is not inconceivable, expecially in a setting such as benchmark TC negotiations, that the boundaries on the negotiated TC are given by each party's desired solution, meaning that

$$\underline{\theta}_t + \bar{\theta}_t = \arg\max_\theta \mathrm{E}[\Pi_s \mid \theta_t], \tag{4.31}$$

$$\underline{\theta}_t = \arg\max_\theta \mathrm{E}[\Pi_m \mid \theta_t]. \tag{4.32}$$

Although one side might accept an outcome which is worse compared to the disagreement payoff, it is not in the interest of the other party to impose such terms. There is sufficient evidence to demonstrate that smelters were unable to operate at 2017-2018 spot terms, resulting in shutdowns and leading analysts to expect that the "pinch on zinc smelting profits could escalate tightness in years to come as a lack of investment in new smelting capacity is expected to become the next bottleneck."[36] This sentiment was echoed by Trafigura, who announced in 2017 that under-investment would be a key feature of the zinc market going forward.[37]

It is not in the long-term interest of miners, or smelters for that matter, to force their trading partners out of the market. As a producer of zinc concentrate, with a total production of 0.7 million metric tons of non-ferrous metals in 2017, Trafigura exploits both zinc mines in Peru and Cuba and possesses a sizeable 31% stake in zinc miner Terrafame. It therefore seems that the concerns of other zinc miners should also be present when Trafigura negotiates TCs with smelters at arm's length.

No economic sense Sexton (2017) states that it is unlikely that a supplier would engage in unfair practices with a buyer if this disrupts commercial relationships. This line of reasoning is reflected in the high estimate on $\underline{\theta}$. Moreover, it seems that this would especially be the case if the supplier possesses a stake in the buyer, representing sizeable sunk costs which are not recovered in the case of exit. Following this logic, the deals between Trafigura and Nyrstar suggest, absent other explanations, a lack of economic sense if it were not for the fact that they allowed Trafigura to acquire Nyrstar's assets. Doing so would allow them to capture future benefits when the

[36] See "Wide gap in Zinc TCs reflect market near its turning point", (2018, May 3), ING.
[37] See Trafigura's 2017 annual report, p. 6.

zinc cycle turned in favour of smelters.

It could be argued that - due to the fact that they were a commodity trader and not exclusively committed to zinc mining - Trafigura did not share a position similar to that of other miners. However, what zinc production they possessed would require a downstream trading partner, but given their close relationship with Nyrstar, a new partner would likely not be as valuable. The supply deals they made with Nyrstar could not be unilaterally terminated and Trafigura possessed a right of first refusal on Nyrstar's zinc metal output, which made Nyrstar a (de facto) captive supplier and buyer (Gereffi et al., 2005).

The no economic sense criterion does not require the undertaking firm to not benefit from its conduct in the short-run. Indeed, if a firm charges excessive prices, this is assumed to be to its advantage exactly in the short-run. Following Werden (2005), the key criterion is that: "[C]onduct fails the no economic sense test if it is expected to yield a negative payoff, net of the costs of undertaking the conduct, and not including any payoff from eliminating the competition". That is, conduct which results in a smelter's insolvency would seemingly not be in the long-run interest of a miner, with the clear exception if it allows them to capture some type of future benefits resulting from the smelter's exit.

4.6 Conclusion

In this chapter, we presented a framework to evaluate alleged claims of excessive pricing in a business-to-business setting, using dictatorial outcomes within a cooperative bargaining model as competitive benchmarks. As an empirical application, we provided a thorough examination of the bargaining process in the zinc market, in order to connect market fundamentals to bargaining outcomes. Using the asymmetric Nash bargaining solution, we derived the outcome of negotiations should zinc miners possess all bargaining power, which yields a benchmark against which to compare alleged excessive prices.

In the case of the deals between Nyrstar and Trafigura, it was shown that prices charged exceeded the benchmark. It was argued that - as opposed to horizontal competition - vertical competition tends to impose a limit on how much the margins of either side are squeezed as a result of bilateral dependencies. Based on both quantitative and anecdotal evidence, this seems to have been the case in the zinc supply chain. Trafigura did not exhibit a similar concern. In turn, this could indicate a lack of economic sense, absent other reasonable explanations.

As an afterthought, the findings presented here suggest that the EC's remedy policy might need rethinking. Nyrstar's offtake contracts for finished zinc were considered a prize, attracting more than ten bidders in 2013, with one of the bidders stating that "[e]veryone salivates when a deal like this becomes available".[38] However, prohibiting Glencore from dealing with Nyrstar led to the latter losing an important bargaining chip. Although merger remedies might solve short-term concerns, this should not prevent the EC from considering the long-term perspective on how their decisions shape the market. Especially considering that economists have increasingly questioned the lenient stance merger review takes when approving mergers that raise concerns.[39]

[38] See "Nyrstar's $700 mln zinc offtake attracts more than ten bidders", Reuters M&A America (2013, March 6).
[39] See Kwoka (2014) for the US or Davies and Lyons (2008) for the EU.

Bibliography

Akman, Pinar and Luke Garrod (2011). "When are excessive prices unfair?" In: *Journal of Competition Law & Economics* 7.2, pp. 403–426.

Binmore, Ken, Ariel Rubinstein, and Asher Wolinsky (1986). "The Nash bargaining solution in economic modelling". In: *The RAND Journal of Economics*, pp. 176–188.

Blas, Javier and Jack Farchy (2021). *The World for Sale: Money, Power, and the Traders Who Barter the Earth's Resources*. Oxford University Press.

Bresnahan, Timothy F (1989). "Empirical studies of industries with market power". In: *Handbook of industrial organization* 2, pp. 1011–1057.

Brito, Dagobert L, AM Buoncristiani, and MD Intriligator (1977). "A new approach to the Nash bargaining problem". In: *Econometrica: Journal of the Econometric Society*, pp. 1163–1172.

Cahuc, Pierre, Fabien Postel-Vinay, and Jean-Marc Robin (2006). "Wage bargaining with on-the-job search: Theory and evidence". In: *Econometrica* 74.2, pp. 323–364.

Collard-Wexler, Allan, Gautam Gowrisankaran, and Robin S Lee (2019). ""Nash-in-Nash" bargaining: a microfoundation for applied work". In: *Journal of Political Economy* 127.1, pp. 163–195.

Crespi, John M, Tina L Saitone, and Richard J Sexton (2012). "Competition in US farm product markets: Do long-run incentives trump short-run market power?" In: *Applied Economic Perspectives and Policy* 34.4, pp. 669–695.

Crook, T Russell and James G Combs (2007). "Sources and consequences of bargaining power in supply chains". In: *Journal of operations management* 25.2, pp. 546–555.

Davies, Stephen and Bruce Lyons (2008). *Mergers and merger remedies in the EU: assessing the consequences for competition*. Edward Elgar Publishing.

Dewispelaere, Jeroen and Chloé Binet (2019). "New Rules in B2B Relationships Seek to Reinforce Competition and to Balance Unequal Bargaining Power". In: *Eur. Competition & Reg. L. Rev.* 3, p. 294.

Evans, David S and A Jorge Padilla (2005). "Excessive prices: Using economics to define administrable legal rules". In: *Journal of competition law and economics* 1.1, pp. 97–122.

Ezrachi, Ariel and David Gilo (2009). "Are excessive prices really self-correcting?" In: *Journal of Competition Law and Economics* 5.2, pp. 249–268.

Gereffi, Gary, John Humphrey, and Timothy Sturgeon (2005). "The governance of global value chains". In: *Review of international political economy* 12.1, pp. 78–104.

Ghysels, Eric, Pedro Santa-Clara, and Rossen Valkanov (2004). "The MIDAS touch: Mixed data sampling regression models". In.

Ghysels, Eric, Arthur Sinko, and Rossen Valkanov (2007). "MIDAS regressions: Further results and new directions". In: *Econometric reviews* 26.1, pp. 53–90.

Gilbert, Christopher L (2021). "Monopolistic supply management in world metals markets: How large was Mount Isa?" In: *Journal of Commodity Markets* 21, p. 100125.

Horn, Henrick and Asher Wolinsky (1988). "Bilateral monopolies and incentives for merger". In: *The RAND Journal of Economics*, pp. 408–419.

Jenny, Frederic (2018). *Abuse of dominance by firms charging excessive or unfair prices: An assessment*. Springer.

Johnson, Simon, Rafael La Porta, Florencio Lopez-de-Silanes, and Andrei Shleifer (2000). "Tunneling". In: *American economic review* 90.2, pp. 22–27.

Kalai, Ehud (1977). "Nonsymmetric Nash solutions and replications of 2-person bargaining". In: *International Journal of Game Theory* 6.3, pp. 129–133.

Kwoka, John (2014). *Mergers, merger control, and remedies: A retrospective analysis of US policy*. Mit Press.

Lang, John Temple and Robert O'Donoghue (2002). "Defining legitimate competition: how to clarify pricing abuses under Article 82 EC". In: *Fordham Int'l LJ* 26, p. 83.

Mérel, Pierre and Richard J Sexton (2017). "Buyer power with atomistic upstream entry: Can downstream consolidation increase production and welfare?" In: *International Journal of Industrial Organization* 50, pp. 259–293.

Motta, Massimo, Michele Polo, and Helder Vasconcelos (2007). "Merger remedies in the European Union: an overview". In: *The Antitrust Bulletin* 52.3-4, pp. 603–631.

Nash, John (1950). "The bargaining problem". In: *Econometrica: Journal of the econometric society*, pp. 155–162.

— (1953). "Two-person cooperative games". In: *Econometrica: Journal of the Econometric Society*, pp. 128–140.

Rubinstein, Ariel (1982). "Perfect equilibrium in a bargaining model". In: *Econometrica: Journal of the Econometric Society*, pp. 97–109.

Schroeter, John R, Azzeddine M Azzam, and Mingxia Zhang (2000). "Measuring market power in bilateral oligopoly: the wholesale market for beef". In: *Southern economic journal* 66.3, pp. 526–547.

Sexton, Richard J (2017). "Business-to-business unfair trading practices in the food supply chain: what are they? how common are they? and what should we do about them?" In: *Paper presented at the workshop on UTPs in the food supply chain, Brussels 17-17 July*.

Thomson, William (1994). "Cooperative models of bargaining". In: *Handbook of game theory with economic applications* 2, pp. 1237–1284.

Van Cayseele, Patrick and Dave Furth (1996). "Bertrand-Edgeworth duopoly with buyouts or first refusal contracts". In: *Games and Economic Behavior* 16.2, pp. 153–180.

Vickers, John (2005). "Abuse of market power". In: *The Economic Journal* 115.504, F244–F261.

Werden, Gregory J (2005). "Identifying exclusionary conduct under Section 2: The no economic sense test". In: *Antitrust LJ* 73, p. 413.

Wright, Joshua D and John M Yun (2019). "Use and Abuse of Bargaining Models in Antitrust". In: *U. Kan. L. Rev.* 68, p. 1055.

Wright, Randall, Philipp Kircher, Benoit Julien, and Veronica Guerrieri (2021). "Directed search and competitive search equilibrium: A guided tour". In: *Journal of Economic Literature* 59.1, pp. 90–148.

Ying, Ng Yun, Hu Shuyi, Low Jun Yang Leroy, Megan Tam Yee Kwun, Tan Yi Jie, and Witney Phua Yiyu (2021). "TRAFIGURA REACH FOR THE (NYR) STAR". In: *Corporate Governance Case Studies*, p. 445.

Appendix C

Appendix Chapter 4

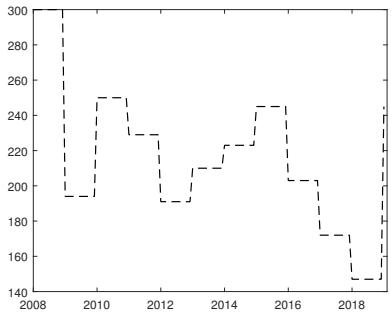
C.1 The European Zinc Market

Table C.1: Market shares for zinc metal in the EEA (2014).
Source: DG. Comp.

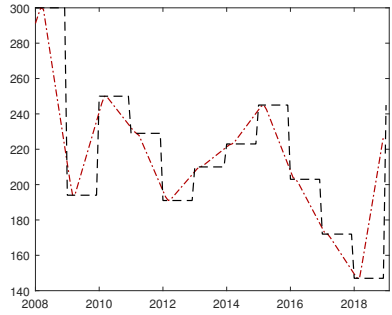
Company	Production share	Supply share	Status	Metals
Nyrstar	30-40%	20-30%	smelter/miner	zinc, lead
Trafigura	-	0-5%	trader/miner	-
Glencore	30-40%	30-40%	smelter/miner	copper, nickel, zinc, lead
Boliden	20-30%	20-30%	smelter/miner	copper, nickel, zinc, lead
ZGH Boleslaw	5-10%	5-10%	smelter/miner	zinc, lead
KCM AD	0-5%	0-5%	smelter	zinc, lead
Noble	-	5-10%	trader	-
Louis Dreyfus	-	0-5%	trader	-
MRI Group	-	0-5%	trader	-
Other	0-5%	0-5%	unknown	-

C.2 Interpolation

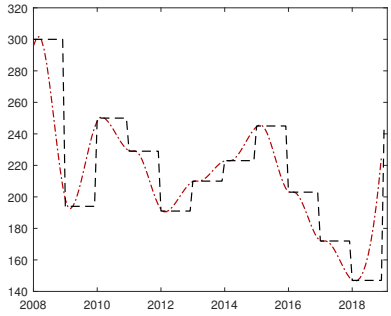
As an alternative approach to the MIDAS regression, we construct a hypothetical monthly benchmark TC, denoted $\hat{\theta}_t$, which can be thought of as the expected outcome of negotiations should benchmark TCs be updated on a monthly basis.



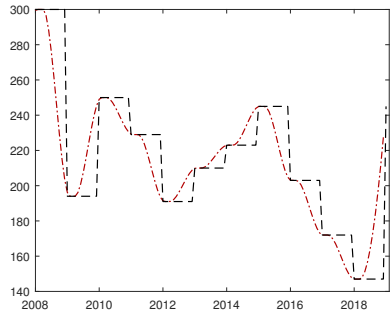
(a) Benchmark TC



(b) Linear



(c) Cubic spline



(d) Piecewise polynomial

Figure C.1: Interpolations.

This is done by taking a weighted average of the benchmark TC in a given month and the TC one year ahead using interpolation.

In order to decide between which data points to interpolate, we run an algorithm which iterates over all possible intervals, after which the following regression

$$\hat{\theta}_t = \beta_0 + \beta_1 \theta_t^s + \epsilon_t, \tag{C.1}$$

is estimated using the interpolated benchmark TC as the dependent and the observed spot TC as the independent variable. The optimal interpolation scheme is considered to be the one which minimizes the sum of squared residuals for this regression. Interpolation is performed using three different methods - linear, piecewise polynomial and cubic spline interpolation - yielding similar results, which support the findings of the MIDAS regression analysis.

Table C.2: Optimal interpolation points

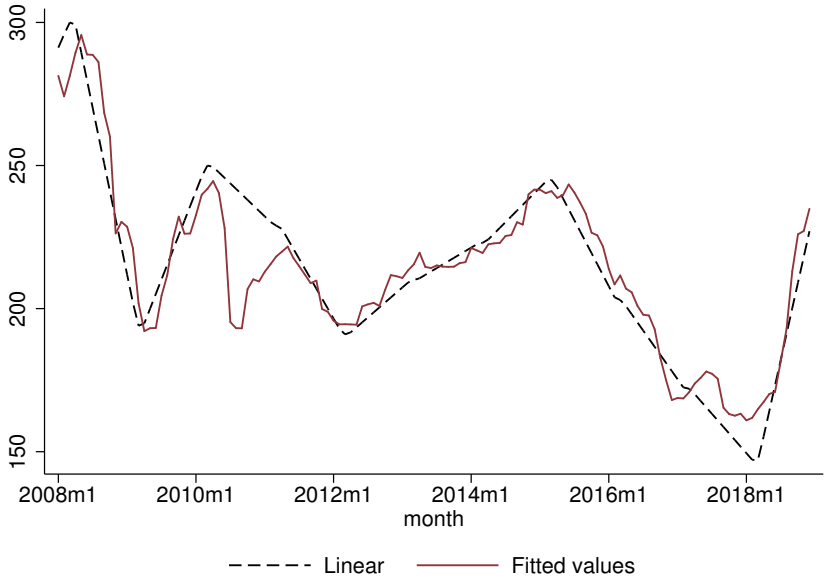
Method	Point 1	Point 2
Linear	February	March
Cubic	January	March
Piecewise	January	March

Table C.3: OLS estimation results

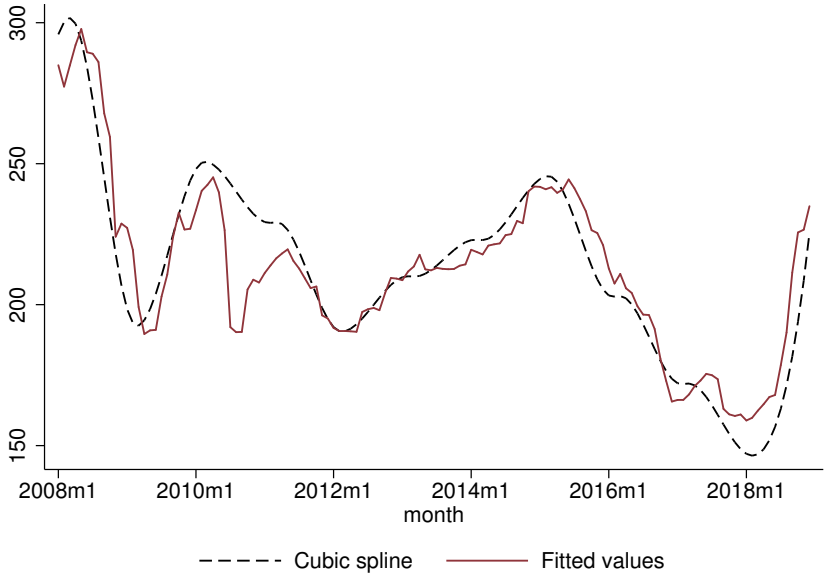
		Linear	
Variable	(1)	(2)	(3)
Constant	159.74***	101.10***	112.41***
	(2.68)	(9.34)	(10.15)
θ_t^s	0.41***	0.41***	0.39***
	(0.02)	(0.02)	(0.02)
steel_t		0.27***	0.29***
		(0.04)	(0.04)
$\bar{p}_t$			-0.006
			(0.003)
R-squared	0.80	0.85	0.86
		Cubic	
Constant	155.76***	99.22***	107.79****
	(2.91)	(10.47)	(11.55)
θ_t^s	0.43***	0.43***	0.42***
	(0.02)	(0.02)	(0.02)
steel_t		0.26***	0.27***
		(0.05)	(0.05)
$\bar{p}_t$			-0.004*
			(0.002)
R-squared	0.78	0.83	0.83
Observations		132	

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$, Robust standard errors in parentheses.

It is found that the spot TC most accurately reflects the actual benchmark in the first quarter of the year, as the interpolated values are closest to the annual benchmark during this interval. This is consistent with the fact that negotiations take place at this time, meaning spot TCs are assumed to most accurately represent the current supply-demand imbalance. The hypothetical benchmark for each method is depicted on figure C.1. These findings also support the earlier made claim that anual TCs are largely determined by the spot TCs in the first quarter of each year. Table C.3 reports the OLS regression results when regressing observables on the hypothetical monthly benchmark. Figure C.2 depicts the fit.



(a) Linear



(b) Cubic

Figure C.2: Fitted values.

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