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Market Shares as Collusive Marker: Evidence from the European Truck Industry*

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Abstract

Collusion theory robustly predicts non-cartel rivals to raise their price and increase their output. As the typical cartel cuts back production, its competitors are expected to gain market share during the collusive period and to lose market share in the period following the cartel's demise. We provide empirical support for this prediction by showing that it applied to the European truck cartel. We also illustrate how our analysis can be used in the prosecution stage. One truck manufacturer denied cartel participation, whereas the proposed market share test supports the European Commission's finding that this firm was, in fact, a member.

Keywords: Cartel Detection; Competition Law Enforcement; European Truck Cartel; Incomplete Cartels; Umbrella Pricing.

JEL Classification: L1, L4.

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1 Introduction

About a decade ago, the European Court of Justice (ECJ) argued that:[1]

> "...it cannot be ruled out that a competing undertaking, outside the cartel in question, might choose to set the price of its offer at an amount higher than it would have chosen under normal conditions of competition, that is, in the absence of that cartel. In such a situation, even if the determination of an offer price is regarded as a purely autonomous decision, taken by the undertaking not party to a cartel, it must none the less be stated that such a decision has been able to be taken by reference to a market price distorted by that cartel and, as a result, contrary to the competition rules."

With this statement, the ECJ explicitly acknowledged the possibility of umbrella pricing, which in turn paved the way for umbrella damage claims, *i.e.*, compensation claims by non-cartel members' buyers for having paid 'too much' during the cartel's life span.[2]

The logic underlying umbrella pricing is rooted in the theory of incomplete (or partial) cartels, *i.e.*, cartels with less than one hundred percent market share. Consider an industry with a typical cartel that raises price above competitive levels. When this cartel is not all-inclusive, the cartel price serves as an umbrella below which non-cartel members are able and willing to raise their prices too. Specifically, the price increase by cartel members presumably induces part of their buyers to switch to nonconspirators. This demand increase provides the cartel's rivals with an incentive to both raise their price and expand their output. Given a reduction of total industry supply, this implies that non-cartel members gain market share at the expense of the cartel.

Although this umbrella effect is well established in the theory of collusion, empirical evidence is relatively scarce and mainly anecdotal. Barbezat (1996), for example, describes how French inter-war steel cartels failed to prevent non-cartel rivals from undercutting the cartel price, which resulted in a market share loss. In case of the well-documented global citric acid and vitamin price conspiracies, Chinese competitors saw their market shares grow during the collusive period and expansion of fringe supply has been argued to significantly undermine the stability of the vitamin C cartel.[3] Consistent with the theory of umbrella pricing, Hüschelrath & Veith (2016) find that the cartel breakdown in the German cement industry resulted in lower prices for both the colluding firms and those that remained outside the agreement. Bos et al. (2019) examine changes in company valuations at the time of the cartel's collapse. They find that cartel death

[1] Case C-557/12, *Kone AG and Others*, June 5, 2014.

[2] For an in-depth discussion of such umbrella effects, see Inderst et al. (2014).

[3] See, *e.g.*, Connor (1998), Harrington (2006b) and Igami & Sugaya (2022) as well as some of the references therein.

negatively affected stock prices of both conspirators and nonconspirators, which suggests that the whole industry benefited from the cartel's presence.[4]

In this paper, we study the umbrella effect by examining the recent European truck cartel. In 2016, the truck manufacturers DAF, Daimler, Iveco, MAN, and Volvo/Renault received a record-breaking fine of almost €3 billion in total for fixing prices in the European truck market. About one year later, another fine of close to €1 billion was added for the Swedish truck manufacturer Scania. The cartel was not all-inclusive and faced competition from several American, European and Asian fringe producers. We evaluate the theory by scrutinizing market share dynamics during the cartel's life span and the years following its demise.

In the post-cartel period, there was a significant and persistent decrease of non-cartel rivals' market share. Following this observation, we perform a structural break test to determine the date of cartel death and demonstrate that it roughly coincides with the official cartel termination date. By using a control group approach, we provide empirical evidence that this substantial change in the market share distribution was the result of the cartel's breakdown. Taken together, these findings therefore confirm the theoretical prediction and suggest that the competitors of the European truck cartel indeed enjoyed umbrella benefits.

Our analysis not only provides empirical support for the theory underlying umbrella pricing, but can also be used as a cartel detection tool. Although market share dynamics is driven by many factors, a persistent decrease in the percentage of industry sales by a given group of sellers may be indicative of cartel activity. Such a pattern is particularly suspect when followed by a relatively sharp rise in market shares, something one would expect after the cartel's collapse. Moreover, scrutinizing market share developments is potentially useful in determining (non-)cartel membership. Specifically, a supplier that saw its market share decline during the collusive period and increase after the cartel's breakdown is suspect of being a member. We illustrate this by analyzing the case of Scania, which claimed to have been an outsider to the cartel. Contrary to this claim, however, the proposed market share test identifies it as a cartel member, thereby supporting the conclusion of the European Commission that Scania had taken part in the conspiracy.

Our study naturally relates to the literature on less than all-inclusive cartels. Bos & Harrington (2015) examine how competition policy might theoretically affect cartel size. Bos et al. (2020) explore the formation of incomplete cartels when the products involved are vertically differentiated. In a related fashion, Bos & Marini (2022) study the sustainability of partial cartels in quality-segmented markets. Both these studies establish

[4]There is also some recent experimental work studying partial cartels in a controlled laboratory setting. See, *e.g.*, Gomez-Martinez (2017), Odenkirchen (2018), and Clemens & Rau (2022).

how cartel stability critically depends on the costs of producing (extra) quality. De Roos & Smirnov (2021) show that a less than all-inclusive cartel may induce intertemporal price dispersion when consumers are imperfectly attentive. As yet another recent example, Madio & Pignataro (2023) consider the formation of a partial cartel in a linear demand Cournot game with capacity constraints. Among other things, they provide conditions under which a relatively small, capacity-constrained, supplier would not take part in a cartel. More generally, the extant literature suggests a positive relationship between cartel participation and firm size.[5]

This paper also adds to the growing body of work on economic methods of cartel detection. This literature commonly distinguishes between structural and behavioral screens.[6] Structural methods aim to identify market characteristics that make an industry prone to collusion. For example, collusion is argued to be *ceteris paribus* more likely in markets with a few firms, homogeneous products and sufficiently stable demand.[7] Behavioral methods aim to identify suspect firm conduct. For instance, the presence of a cartel is likely to reduce price variation.[8] The proposed market share test falls within the second category since it screens for suspect market share patterns.

Partly fueled by the latest developments in data analytics, quite a few new cartel screens have been recently proposed.[9] Boswijk et al. (2019) and Crede (2019) adopt structural break tests to detect collusion and determine the actual birth and death dates of cartels. They search for structural breaks in price patterns, whereas our focus is on output and the corresponding market share dynamics. A non-exhaustive list of other recent examples includes Huber & Imhof (2019), Wachs & Kertész (2019), Silveira et al. (2022), Silveira et al. (2023), and Pires & Skjeret (2023). We envision how novel data (analytics) technology may facilitate the use of such screens, including the proposed market share test, in antitrust practice. Indeed, as we argue in this article, carefully scrutinizing market share patterns can identify red flags that may guide competition agencies in their decision on where to launch in-depth investigations.

The next section provides a brief discussion of the theory of cartels that are not all-inclusive. Section 3 contains an empirical analysis of the European truck cartel. The implied market share test is applied in Section 4. Section 5 concludes.

[5] See, for example, Donsimoni (1985) and Bos & Harrington (2010).

[6] See Harrington (2006a).

[7] See Grout & Sonderegger (2005).

[8] See Abrantes-Metz et al. (2006) and Harrington (2006a).

[9] For a discussion of this trend, see Abrantes-Metz & Bajari (2010), Deng (2017), Beth & Gannon (2022), and Harrington & Imhof (2022).

2 Theoretical Background

In this section, we briefly discuss the theory of cartels that face competition from non-cartel rivals. This serves as a foundation for the empirical analysis in the ensuing sections.

2.1 The Rule: Non-Cartel Members gain Market Share

Collusion in the presence of independent competitors has been analyzed in a wide variety of settings. A common takeaway from these studies is that less than all-inclusive cartels create a price umbrella that enables non-cartel members to increase both their price and their sales volume. Given that the cartel cuts back production, this implies that non-cartel members gain market share.

To illustrate, consider a symmetric price-setting game with a given set of firms: $N = \{1, \ldots, n\}$, where $n \geq 3$. Products are differentiated and each firm $i \in N$ chooses a price $p_i \in [0, \overline{p}]$ so that $[0, \overline{p}]^n$ is the set of all price profiles. Firm i's profit is given by $\pi_i(p_i, p_{-i})$, where $p_{-i} = \{p_1, ..., p_{-i}, p_{i+1}, ..., p_n\}$ is the vector of its rivals' prices. Profit functions are assumed to be twice continuously differentiable with:

$$\frac{\partial^2 \pi_i(p_i, p_{-i})}{(\partial p_i)^2} < 0 \text{ and } \frac{\partial^2 \pi_i(p_i, p_{-i})}{\partial p_i \partial p_j} > 0, \tag{2.1}$$

and

$$\left| \frac{\partial^2 \pi_i(p_i, p_{-i})}{(\partial p_i)^2} \right| > \sum_{i \neq j} \frac{\partial^2 \pi_i(p_i, p_{-i})}{\partial p_i \partial p_j}, \forall i, j \in N \text{ and } i \neq j. \tag{2.2}$$

Thus, profits are strictly concave in own price and marginal profitability increases with the prices set by rivals. Moreover, own price effects dominate the combined cross price effects. These are standard assumptions that hold when demand is linear, for example.[10]

If $\partial \pi_i(0, p_{-i})/\partial p_i > 0$ and $\overline{p}$ is high enough, then there exists an interior pure-strategy price equilibrium that is characterized by the following first-order conditions:

$$\frac{\partial \pi_i(r_i(p_{-i}), p_{-i})}{\partial p_i} = 0, \forall i \in N, \tag{2.3}$$

where $r_i(p_{-i})$ is firm i's best-response to its rivals' prices.

Now suppose that a less than all-inclusive cartel forms, which raises price above equilibrium levels. If non-cartel rivals set best-response prices, then such a cartel induces an industry-wide price increase. To see this, note that one can apply the implicit function theorem to obtain:

$$\frac{\partial r_i(p_{-i})}{\partial p_j} = -\frac{\partial^2 \pi_i / \partial p_i \partial p_j}{\partial^2 \pi_i / (\partial p_i)^2}, \ i \neq j, \tag{2.4}$$

which is positive by (2.1) and less than one by (2.2). The cartel thus creates a price umbrella under which its competitors raise their price too (*i.e.*, prices are strategic complements). Moreover, the price difference between cartel members and non-cartel members

[10] See, *e.g.*, Deneckere & Davidson (1985).

increases with the latter becoming relatively cheaper. Under the plausible assumption that buyers take relative prices into account, this implies that non-cartel members gain market share.

Not surprisingly then, the illustrated effect holds generically and has been established in a wide variety of oligopoly models. For example, d'Aspremont et al. (1983) and Shaffer (1995) show that the fringe grows in size when the cartel operates as a price and quantity leader, respectively. It is also present when firms produce perfect substitutes and face capacity constraints as in Bos & Harrington (2010) or when products are vertically differentiated as in Bos et al. (2020). There are many more examples.[11]

2.2 An Exception to the Rule: Dominant-firm Cartel Conduct

There is one possible notable exception to the rule that non-cartel members gain market share: *dominant-firm cartel conduct*. Since growing outsiders potentially undermine the profitability and, ultimately, the stability of a cartel, cartels have an incentive to restrict expansion of non-cartel supply.

Dominant-firm behavior by cartels has been frequently observed in antitrust practice. A study by Heeb et al. (2009), for example, reports on a sample of known cartels and shows that they engaged in a broad range of dominant-firm strategies (*e.g.*, exclusionary contracts, purchasing from non-cartel rivals, *etc.*). Harrington et al. (2018) offer a taxonomy of four different types of methods to curtail non-cartel supply, referred to as takeover, starvation, coercion, and bribery. They describe how a German cement cartel effectively controlled imports from non-cartel rivals by bribing intermediaries.[12] Marshall et al. (2019) focus on the possibility of driving the cartel's rivals out of business, an extreme form of coercion. They argue that successfully suppressing intra-cartel rivalry is a precondition to engage in such predatory behavior.

This and related work illustrates the wide variety of methods that cartels employ to curtail non-cartel supply. It should be emphasized, however, that not all of these tactics undermine the rule that non-cartel rivals gain market share. Purchasing directly from fringe firms, for instance, prevents (excessive) business stealing, but still increases their share of the pie. More generally, the rule applies as long as the output reduction by cartel members exceeds that of non-cartel members. That said, sufficiently aggressive monopolization conduct by cartels does potentially reduce outsiders' market share. It is noteworthy that this is a risky strategy. After all, dominant-firm cartel conduct that severely harms outsiders may induce them to inform the competition authority, which in turn might trigger an investigation. In the pre-insulated pipe cartel, for example, the

[11] See, *e.g.*, Escrihuela Villar (2003) and Bos (2009) as well as some of the references therein.

[12] 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.

Swedish undertaking Powerpipe AB saw itself confronted with a boycott of its buyers and suppliers to which it responded by filing a complaint to the European Commission.[13]

Before taking the theory to the data, let us conclude this section by noting there is no reported evidence that the European truck cartel engaged in dominant-firm conduct.[14]

3 Empirical Analysis

Given that there is no severe monopolization conduct, we may expect cartel formation to boost the sales volume of non-cartel members. In combination with an output reduction by the cartel, this implies an increase of the outsiders' market share during the collusive period and a decrease of the outsiders' market share in the period following the cartel's demise. In this section, we test this hypothesis by studying the European truck cartel.

3.1 European Truck Cartel

On September 20th, 2010, German truck manufacturer MAN informed the European Commission about the cartel in exchange for leniency. Subsequent investigations put an end to a price-fixing conspiracy that spanned the entire EEA market and lasted for about one and a half decade (1997-2011). The cartel was comprised of the six largest European truck manufacturers: DAF, Daimler, Iveco, MAN, Scania, and Volvo/Renault. These producers colluded on the price of medium commercial vehicles (6-16 tons) and heavy commercial vehicles (over 16 tons).[15] In the following, we refer to these as commercial vehicles (CVs) to be distinguished from light commercial vehicles (LCVs).

In the CV segments, price determination starts with a gross price list that is issued by the respective companies' headquarters. This list contains information about base model prices and available custom assembly options. These lists were initially on paper, but soon replaced by digital 'configurators'. CVs are imported through distributors, which pay a transfer price equal to the gross list price corrected for possible discounts. These distributors then determine the price for dealerships in a similar fashion. That is, there is a distributor gross price list to which potential discounts are applied resulting in a dealer net price. The end consumer pays a price that is determined by the dealerships. Both dealerships and distributors were either independent third parties or wholly-owned.

The European truck manufacturers increased and harmonized their prices at the factory gate level across the EEA. This practice was facilitated by the introduction of the Euro currency, which resulted in EEA-wide gross price lists for all of companies, but

[13] See Case No IV/35.691/E-4: Pre-Insulated Pipe Cartel, available at: https://eur-lex.europa.eu.

[14] However, as rightly remarked by Heeb et al. (2009), the fact that dominant-firm cartel conduct is not described in case documents does not mean that the behavior did not occur.

[15] Although beyond the scope of this article, it is worth noting that they also delayed the introduction of new emission technologies.

Table 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
Fringe	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
	Other	*Daewoo, Hyundai,...*	204	732	199	295	1438

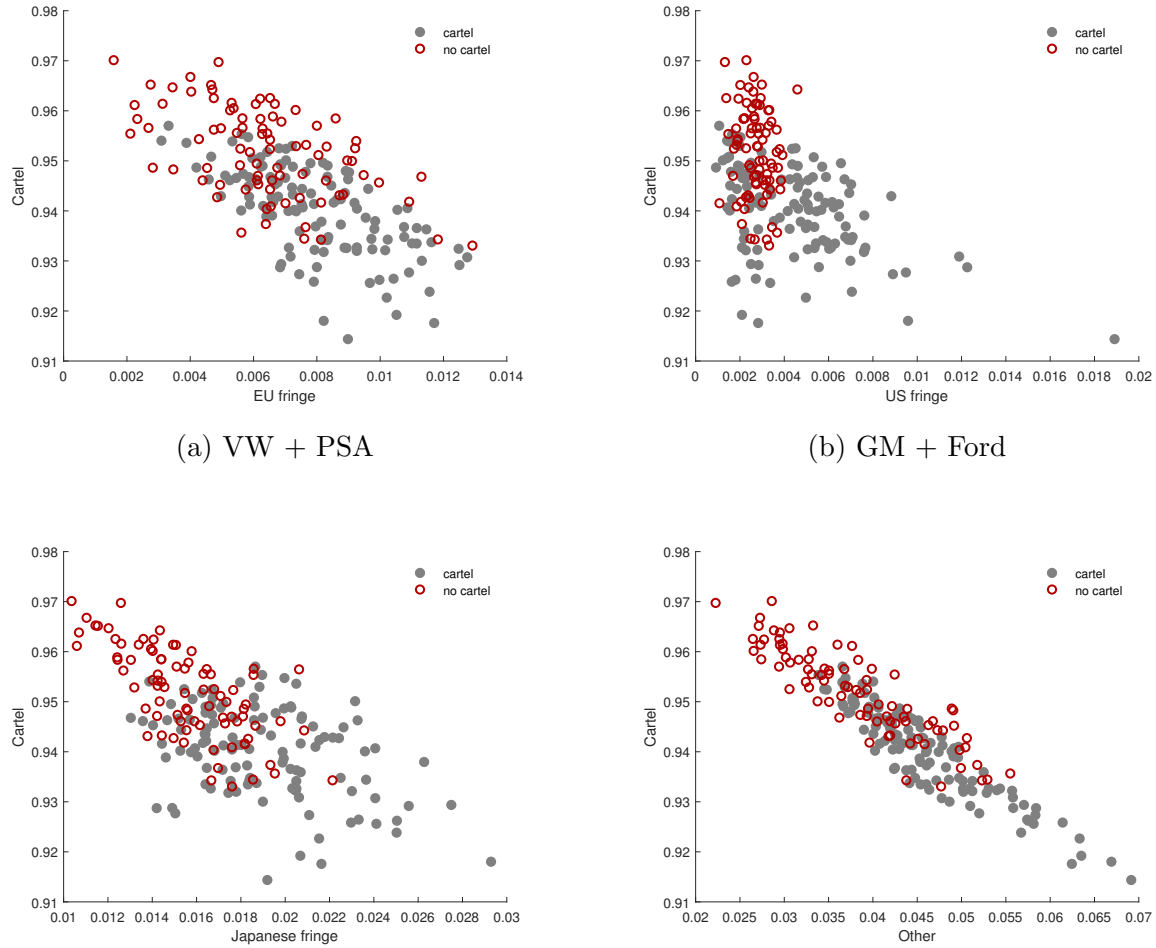
Iveco. Not long after the introduction of the Euro, the cartel members started to systematically exchange information and reduce discounts. Pricing information was regularly shared by means of organized meetings, emails and phone calls. At first, discussions took place at the headquarters, but continued at the German subsidiary level after 2004. Case evidence reveals that the cartel members shared price lists, configurators and coordinated on gross price increases.[16] Although the European Commission did not provide a damage estimate, there is little to no doubt that it amounts to billions of euros.[17]

3.2 Data

To examine the market share effects of the European truck cartel, we used monthly vehicle registrations by manufacturer and type on the EEA market. These data are provided by the European Automobile Manufacturers Association (ACEA) and publicly available since 2001. Our sample covers the period 2001-2017 and contains both medium and heavy commercial vehicle registrations as defined by the European classification system. After 2017, registrations of trucks and buses are no longer reported separately, which would

[16] See CASE AT.39824 -Trucks.

[17] See, for instance, Beyer et al. (2020) who find overcharges on individual net prices of up to 7.6%, which translates into a total damage of about €43.4 billion.



(a) VW + PSA

(b) GM + Ford

(c) Japanese fringe

(d) Other

Figure 1: Scatterplots of monthly CV market shares in the EEA (2001-2017).

complicate the analysis.

Table 1 provides an overview of the number of registrations per truck manufacturer, which are labeled either as (former) cartel member or fringe member. Note that the cartel comprised the largest industry players, which is consistent with the existing theory on incomplete collusion. Regarding the non-cartel members, observe that the Japanese producers are grouped together. This is due to the way in which the data are reported. Japanese registrations are disaggregated across (some of the) individual firms for a few years only.[18] Similarly, registrations for some, relatively small, producers are reported for only part of the sample period. These firms are captured under the header 'Other'. The fringe further consisted of firms from Europe (PSA and VW) and the US (GM and Ford).

Figure 1 plots the market shares of non-cartel rivals relative to the cartel's market

[18]For instance, the registrations for Honda, Toyota and Nissan might be reported for one year, but only for Honda and Toyota in the subsequent year.

share. A firm's market share is the percentage of total registrations in a given month, which is taken as a proxy for the number of sales. Each observation represents a monthly market share of non-cartel members, grouped geographically, relative to the joint market share of cartel members. Specifically, we distinguish between European (1a), US (1b), Japanese (1c) and Other (1d) fringe members. Observations during the collusive period (2001-2010) are given by the gray dots, whereas the post-cartel observations (2011-2017) are indicated by the red circles.

A casual glance at Figure 1 suggests that non-cartel suppliers indeed captured a bigger share of the market during the collusive period and lost market share after the cartel's demise. Moreover, this pattern seems largely independent of the fringe firms' geographic origin. The key question is then: was this the result of cartel activity? It is this question that we now turn to.

3.3 Empirical Strategy

We take a two-step approach to examine whether the cartel's collapse is likely to have caused a decline in non-cartel members' market share. As a first step, we show that the market share dynamics in the CV segments are consistent with the presence of umbrella effects (Section 3.3.1). As a second step, we assess causality by means of a control group approach (Section 3.3.2).

3.3.1 Step 1: Umbrella Effects

Let $q_t = q_{ct} + q_{ot}$ be the total number of registrations in the CV market in a given period t, where q_{ct} and q_{ot} denote the registrations of cartel and non-cartel members, respectively. Note that:

$$\ln q_{ot} = \ln q_{ot} - \ln q_{ct} + \ln q_{ct}, \tag{3.1}$$

which is equivalent to

$$\ln q_{ot} = \ln \left(\frac{s_{ot}}{s_{ct}} \right) + \ln q_{ct}, \tag{3.2}$$

with $s_{it} = \frac{q_{it}}{q_t}$ being the market share in period t. Based on (3.2), we consider the following linear model as a starting point to identify changes in the non-members' market share relative to that of the cartel:

$$\ln q_{ot} = \beta_0 + \beta_1 \ln q_{ct} + \beta_2 \delta_t + \epsilon_t, \tag{3.3}$$

with

$$\delta_t = \begin{cases} 0 & \text{if } t \leq k, \\ 1 & \text{if } t > k, \end{cases} \tag{3.4}$$

where k indicates the end date of the conspiracy. The reason for including this dummy is that if the cartel's demise resulted in a substantial, sudden and persistent reduction

Table 2: Regression Estimates. Equation (3.3)

Coefficients	(1)	(2)
β_0	0.53	1.31***
	(0.54)	(0.41)
β_1	0.67***	0.60***
	(0.05)	(0.05)
β_2	-	-0.26***
		(0.02)
R^2	0.36	0.63
Obs.	204	204

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

of non-rivals' market share, then this would induce a break in the covariate structure through a reduction of the intercept.

Suppose for the moment that $k = 120$, which is the official end date of the cartel as reported by the European Commission. Estimation results are displayed in Table 2, once excluding and once including δ_t (columns (1) and (2), respectively). Observe that the estimate on β_2 is negative and statistically significant, which is in line with expectations.

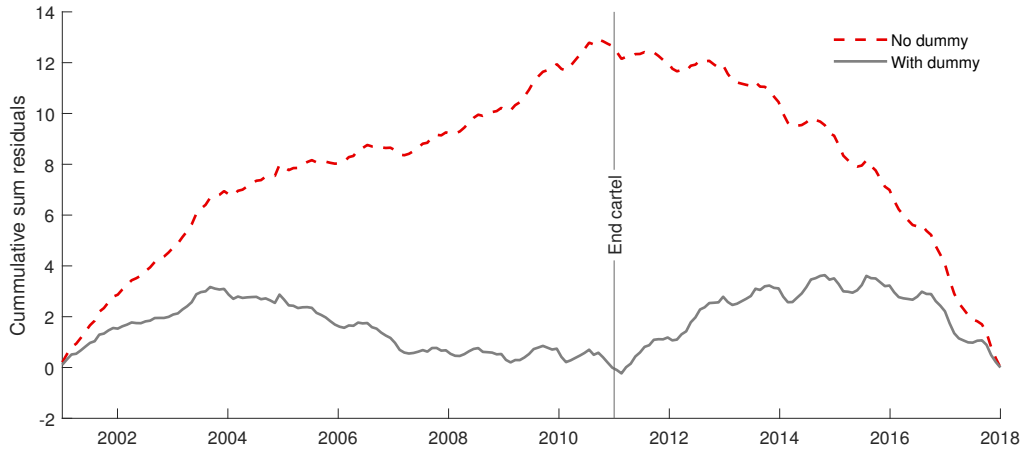


Figure 2: Cumulative sum of OLS residuals, a comparison.

Next, consider the cumulative sum of residuals for specifications (1) and (2) depicted in Figure 2. The OLS estimation absent the switch in competitive conduct (captured by δ_t) introduces endogeneity under the current hypothesis. If outsiders are able to obtain a bigger share of the market when the cartel is active, $\ln\left(\frac{s_{ot}}{s_{ct}}\right)$ is expected to be, on average, larger during the cartel period in comparison to the post-cartel period. As β_0 is a constant and residuals necessarily sum to zero, this introduces serial correlation in the error terms.[19] In case there was a switch from collusion to competition at time $t = k$,

[19]The Breusch-Godfrey test strongly rejects the null hypothesis of no serial correlation in the residuals.

Table 3: Regression Estimates. Equation (3.5)

Coefficients	(1)	(2)
β_0	0.92***	0.67***
	(0.06)	(0.08)
β_1	0.98***	0.91***
	(0.02)	(0.02)
β_2		-0.11***
	-	(0.03)
R^2	-	-
Obs.	204	204

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

one would expect that:

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

which means that the errors tend to be positive when $t \leq k$ and negative when $t > k$. Indeed, Figure 2 shows that the cumulative sum of residuals increases until the end of the cartel. The sum then (necessarily) decreases to zero once $t > k$. Figure 2 further illustrates how a large fraction of the auto-correlation is eliminated by including the dummy.

Serial correlation

As expected, market share fluctuations cannot be solely attributed to cartel activity. Should the only shift in relative market shares take place around the end of the cartel - meaning all change is captured by the dummy δ_t - the estimate on β_1 would be equal to one. As can be seen from Table 2, this is not the case. We therefore expand the previous model to allow for market share fluctuations which are unrelated to competitive conduct.

Consider the following regression:

$$\ln q_{ot} = \beta_0 \hat{r}_t + \beta_1 \ln q_{ct} + \beta_2 \delta_t + \epsilon_t, \tag{3.5}$$

where $r_t = \ln\left(\frac{s_{ot}}{s_{ct}}\right)$. Since the residuals are correlated over time, serial correlation is modelled parametrically. Specifically, r_t is approximated using the following autoregressive model:[20]

$$\hat{r}_t = \alpha_0 + \sum_{i=1}^{2} \alpha_i r_{t-i}. \tag{3.6}$$

Estimation results are reported in Table 3, without and with the dummy variable (columns (3) and (4), respectively). Although the estimate of β_2 remains negative and statistically significant, the estimate on β_1 is close to one.

[20]The number of lags included is motivated by minimizing the AIC and BIC.

Endogenous End Date

In the preceding analysis, we took the cartel's termination date as given ($k = 120$). We now conclude this subsection by showing how one can endogenously identify the end date of the cartel on the basis of the available output data. To that end, consider equation (3.3), 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 that the corresponding sum of squared residuals, denoted $SSR(k)$, may vary depending on when the dummy is switched on. A candidate for the cartel end date would then be:

$$k^* = \arg\min_{[1,T]} \Big\{ SSR(k) \Big\}. \tag{3.7}$$

This break can be identified by running a search algorithm for the optimal partition over the length of the sample.

In order to assess if this break date is statistically significant, a more sophisticated approach can be employed, in which the estimated break date maximizes a test statistic against the alternative hypothesis that there is no break, *i.e.* $\delta_t = 0$.[21] Once identified, one can assess whether the null-hypothesis ('no break') can be rejected. If there appears to be 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.

To illustrate, consider the following model:

$$\ln q_{ot} = \beta_0 + \beta_1 \ln q_{ct} + \delta_t(\beta_2 + \beta_3 \ln q_{ct}) + \epsilon_t. \tag{3.8}$$

It is assumed there is a single unknown break at time k, at which point the dummy δ_t is switched on. Specifically, 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:[22]

$$k^* = \sup_{t \in [t_l, t_u]} \Big\{ W(k) \Big\}. \tag{3.9}$$

Table 4 presents the estimated breakpoint k^*, which is the 118th observation (October 2010). Interestingly, MAN blew the whistle one month prior, which triggered dawn raids two months later. A similar, statistically significant, break date (the 116th observation) is found for (3.5), which accounts for serial correlation. The market share dynamics in the CV segments was thus consistent with the presence of umbrella effects.

[21] See, for instance, Quandt (1960) or Andrews (1993).

[22] We refer to an admissible sample since one needs a cut-off point, demarcating the minimum subsample 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 4: Wald test for a structural break

Basic model (3.3)		
Test	Statistic	p-value
Swald	151.0568	0.0000
Full sample:	1-204	
Trimmed sample:	32-174	
Estimated break:	Oct. 2010 (obs .118)	
Augmented model (3.5)		
Test	Statistic	p-value
Swald	33.4821	0.0000
Full sample:	3-204	
Trimmed sample:	32-174	
Estimated break:	Aug. 2010 (obs .116)	

3.3.2 Step 2: Causality

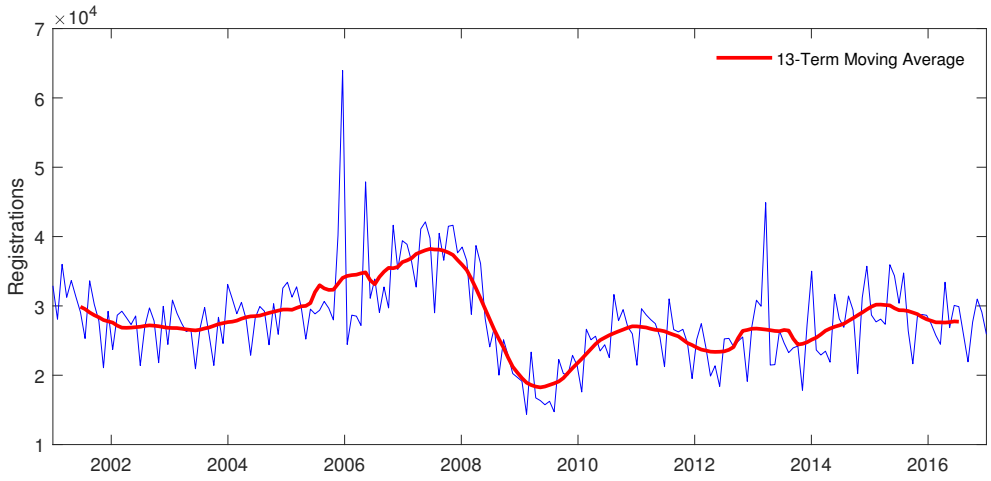
The preceding analysis demonstrates that there was a significant and persistent decrease in the outsiders' market share around the time of the cartel's demise. Though this is suggestive of the hypothesized effect, one should be careful in interpreting this finding, especially since there are some notable differences between the cartel and non-cartel members. In particular, cartel participants (i) sell considerably more trucks than non-participants (see Table 1), and (ii) possess large production facilities in Europe, whereas non-cartel members typically do not.[23] There are thus several sources of heterogeneity that may have potentially contributed to the observed effect, such as region-specific cost shocks, tariffs, trade barriers, shipping costs, or regulatory measures.

One approach to take account of this firm-level heterogeneity is to compare a treatment group with a control group consisting of firms or products that are subject to similar effects and trends.[24] In the following, we use the fact that most truck manufacturers also produce buses, a market in which no collusion has been detected.[25] Buses and trucks are generally produced by the same vertically integrated firms and inputs (*e.g.*, chassis, gearboxes, transmissions, axles, engines, etc.) can either be shared or produced at the same sites. Buses and CVs have been subject to the same emission regulations since they

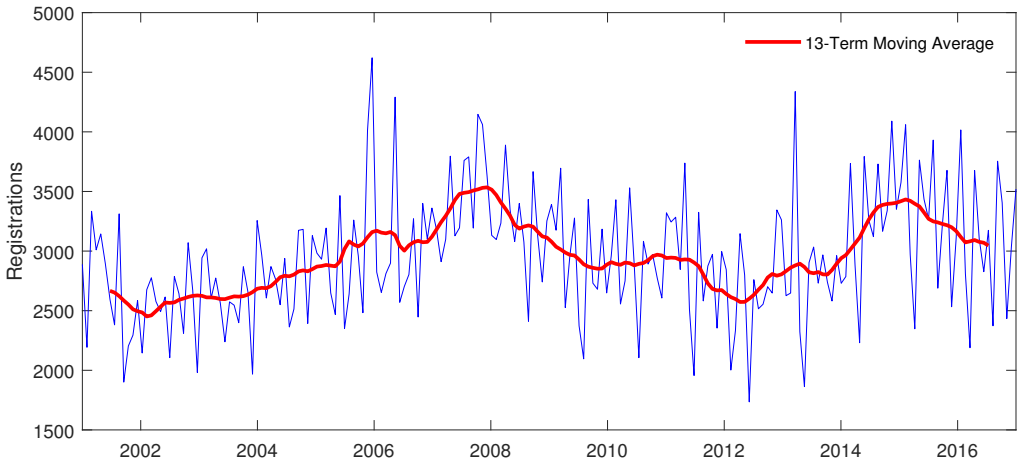
[23] Interactive map Automobile assembly and production plants in Europe.

[24] See, for instance, Angrist (1990), Card & Krueger (2000), and Madrian & Shea (2001).

[25] 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. Of course, one can never be fully sure that a market is without collusive practices.



(a) CV monthly registrations, total



(b) Bus + coach monthly registrations, total

Figure 3: Comparison of market trends (2001-2017).

both belong to the 'heavy-duty diesel engines' category. Last, increased duties and tariffs or region-specific cost shocks are likely to have had a similar impact on the production of buses and trucks. The cartel's demise, triggered by MAN blowing the whistle, constitutes the treatment.

To begin, consider Figure 3, which depicts demand for CVs (3a) and buses (3b) in the sample period. This figure suggests that demand fluctuations are overall comparable. In particular, there are similar, sharp, upticks around the years 2006 and 2013. There is one notable difference during the crisis years, where the demand for CVs dropped significantly more. This may be partly due to customer heterogeneity. Buses are, for instance, often ordered by local governments and less by commercial parties. Bus sales might therefore be less sensitive to business cycle effects. It may also be partly due to cartel activity. Indeed, Rotemberg & Saloner (1986) argue that cartel pricing can be

Table 5: 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	Other*	2.6	18.1
Iveco	14.3	17.9	-		
Total	94.4	73.8	Total	5.4	26.1

* Similar to CVs, registrations from smaller suppliers are grouped together as 'other' in the ACEA's registrations.

countercyclical when monitoring is imperfect. This might explain the more substantial decrease in demand for trucks during the financial crisis. This is also consistent with the fact that non-cartel suppliers experienced a sharp increase of their market share in this period.

Table 5 depicts the average market share of different manufacturers on the EEA truck and bus market, which are derived from ACEA data. Note that 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 on the bus market, 73.8% versus 94.4%. Note further that a firm's market position can differ per product category (*e.g.* Ford has a larger market share on the bus market than on the truck market).

To correct for this, we take a synthetic control approach.[26] Specifically, we assign a weight to the output of each firm on the bus market, which minimizes the distance between the pre-treatment output vectors on the bus and CV market. 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:

$$w_i = \arg\min_{x \in \mathbb{R}^+} \|\mathbf{q}_{ic} - x\mathbf{q}_{ib}\|, \tag{3.10}$$

where $\mathbf{q}_{ij}$ is 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 a $T \times 1$ vector of total registrations, with T being the length of the sample. The synthetic CV market is then given by the following $T \times n$ matrix:

$$\hat{\mathbf{Q}}_c = [\, w_1\mathbf{Q}_{1b} \quad ... \quad w_n\mathbf{Q}_{nb} \,]. \tag{3.11}$$

[26] Such an approach is feasible when a treatment affects a small number of large units, which describes the current case. See Abadie & Gardeazabal (2003) and Abadie (2021).

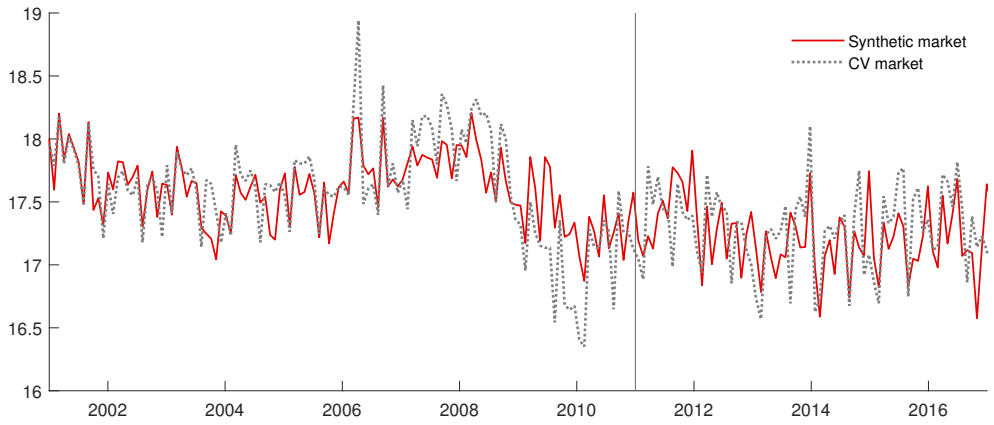


Figure 4: Synthetic CV market, $\ln(q_o) + \ln(q_c)$

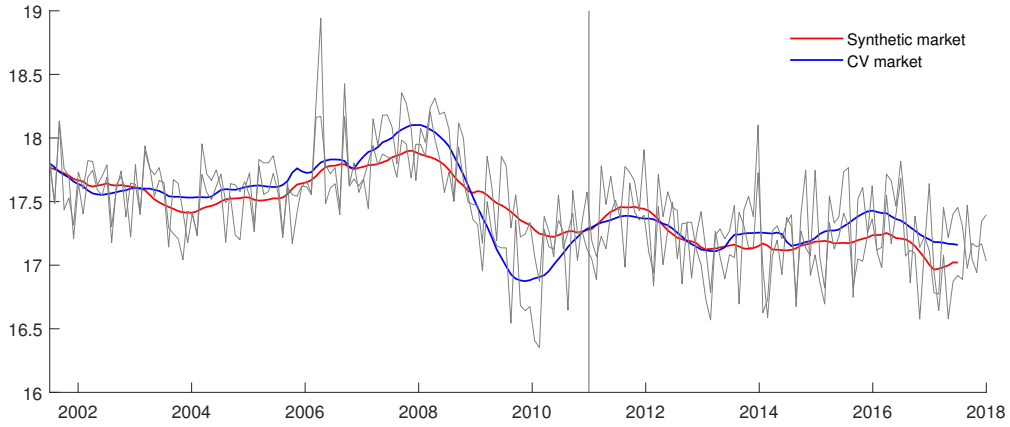


Figure 5: Trend-cycle component, MA(12)

In Figure 5 one can observe that the synthetic market closely mimics the actual CV market until 2008 and that the bus market is indeed less impacted by the recession.

We estimated equation (3.3) for the two control groups, the synthetic CV and the bus market, the results of which are reported in Table 6. Note that the estimate of the β_2 coefficient is positive for both cases, which suggests that the non-cartel member's market share has risen on average after the treatment. Contrary to cartel activity, therefore, firm-level heterogeneity is unlikely to be a driver of the observed market share dynamics.

4 A Market Share Test: The Case of Scania

Toward the end of the 1980s, buyers of cast iron widgets in the Pittsburgh area filed an antitrust suit in response to *a priori* inexplicable price increases. One of the six indicted companies, American Cast Iron Widget (ACIW), insisted on being innocent and instead claimed to have been an outsider to the presumed price-fixing conspiracy. Blair & Romano (1989) provide a detailed discussion of this case and propose a test to assess

Table 6: Control Group Regression Estimates

Coefficient	Synthetic CV	Buses
β_0	-0.84	-0.22
	(0.79)	(0.61)
β_1	0.77***	0.89***
	(0.08)	(0.08)
β_2	0.02	0.10***
	(0.03)	(0.03)
R^2	0.34	0.36
Obs.	204	204

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

ACIW's claim. This test is based on the logic laid out in Section 2, namely that ACIW's output likely would have decreased when it was a cartel member, whereas it would have increased if it was a non-cartel member.

The above analysis allows for a similar cartel membership test. Simply put, a supplier is suspect of being a member when its market share declines during the cartel period, whereas an increase of its market share suggests it was an outsider. The European truck cartel offers an interesting opportunity to apply this test, because one of the accused producers, the Swedish company Scania, denied having been part of the cartel. The other five defendants all settled in exchange for a reduction of the imposed fine. Scania, however, claimed there has been no explicit agreement to elevate prices or to restrict market competition in another way.[27]

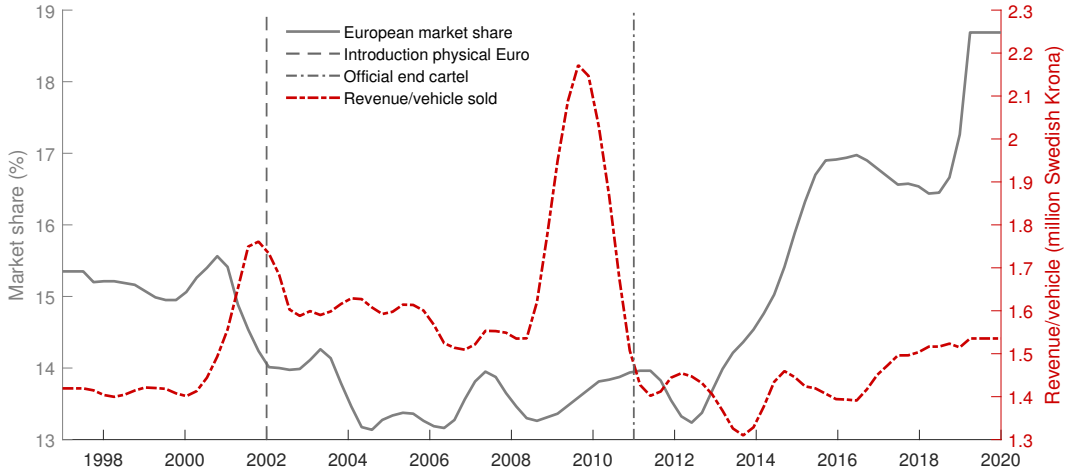


Figure 6: Scania market shares and revenue/vehicle sold in million SEK
Source: Scania's quarterly reports

[27]See CASE AT.39824 -Trucks.

But what does the market share test say? As a starter, consider Figure 6, which depicts Scania's quarterly market share in the heavy CV segment over the relevant period. It also shows its revenue per heavy truck sold, which is taken as a proxy for prices.[28] As can be observed, the formation of the European truck cartel did not go hand in hand with an increase of Scania's market share. On the contrary, Scania's share began to decline around the year 2001, which coincides with the introduction of the Euro currency. Recall that in this period the cartel started with systematically exchanging pan-European price lists with the intent to elevate and harmonize prices. Note further that prices began to rise around this point in time and that Scania's market share grew substantially not long after the cartel's collapse. These casual observations suggest that Scania was a cartel member too.

Let us now more closely evaluate the market share dynamics by performing the following two regressions:

$$\ln q_{ot} = \beta_0 + \beta_1 \ln q_{st} + \epsilon_t, \tag{4.1}$$

and

$$\ln q_{ot} = \beta_0 + \beta_1 \ln(q_{ct} - q_{st}) + \epsilon_t, \tag{4.2}$$

where q_{st} represents Scania's monthly CV registrations. In both cases, employing a Wald test for a structural break yields the same breakpoint (see Table 7 and Table 8) and one that is no different from the estimated breakpoint in Section 3.3 (see Table 4). The first identifies a structural break in Scania's market share trend around the end date of the cartel, whereas the second speaks against the possibility that the break is solely caused by Scania. Taken together, and contrary to Scania's claim, the market share analysis thus points at it being a member of the European truck cartel.

Table 7: Wald test for a structural break. Regression equation (4.1).

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

It should be noted that this market share test is stronger than the output test as proposed by Blair & Romano (1989) for at least two reasons. First, following the theory of incomplete cartels (Section 2), an output increase by an outsider implies a market share increase, but the opposite need not be true. A non-cartel rival may face capacity

[28] Unlike the other manufacturers, Scania only produced heavy trucks. Revenue is deflated using the EU28 industrial PPI. Both trends are smoothed using MA4 seasonal adjustments.

Table 8: Wald test for a structural break. Regression equation (4.2).

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

constraints, for example, which makes it unable to increase its production. Yet, given that the cartel cuts back production, this still implies a gain in market share. Second, the market share test is less sensitive to business cycle effects. For example, during economic booms it may well happen that all firms boost their production, independent of whether they collude or not. However, also in this case non-cartel members are expected to (relatively) expand their business by pricing under the price umbrella provided by the cartel.[29]

That said, there is an important caveat. When performed at the individual level, the employed Wald test not necessarily yields identical breakpoints across conspirators. This may be the case when there are severe market share fluctuations within the cartel.[30] To illustrate, the identified breakpoints for Daimler (116), Volvo (118), MAN (116) and, to a lesser degree, for DAF (106) are comparable to the one of Scania (118). Yet, the same does not hold for Iveco (96) and Renault (142). Furthermore, an increase in a firm's market share need not imply non-participation. Although the cartel's combined market share typically declines, this may not be true for each individual member. A sufficiently integrated cartel may redistribute production across its members to enhance efficiency, for example.

Though it is clear that an increase in market share during the collusive period does not necessarily implies non-participation, a decrease in market share poses a clear 'red flag' for participation. Indeed, provided that the cartel did not engage in severe monopolization conduct, it will be challenging to explain why a supplier operating under a collusive price umbrella would lose customers over time. In other words, although a cartel member potentially passes the test (type 1 error), a non-cartel member is unlikely to fail the test (type 2 error). In that sense, the proposed market share test provides strong support for the European Commission's decision to impose an €880 million fine on Scania for taking

[29] A notable exception is discussed by Montero & Guzman (2010). They show that non-cartel suppliers may lose market share during booms when firms only control their production level and not their selling price.

[30] It is noteworthy that many known cartels contained an explicit market share agreement with the aim to keep market shares stable over time. In case the cartel was less than all-inclusive, it is the cartel member's share of total cartel supply that tended to be stable. See Harrington (2006b).

part in the European truck cartel.[31]

5 Conclusion

The vast majority of uncovered cartels did not encompass all firms in the industry. Existing theories of collusion explain how the emergence of a less than all-inclusive cartel incentivizes non-cartel members to expand their output. Given that the typical cartel cuts back production, this implies non-conspirators to gain market share at the expense of conspirators. In this paper, we provide empirical evidence for this by showing that it applied to the European truck cartel.

In terms of policy implications, the conducted market share analysis is potentially an effective tool in cartel law enforcement. *Ex ante* it may be used as a behavioral screen to spot suspect market behavior. A persistent decline in the combined market share of a group of leading industry players is a tell-tale sign of collusion, for example. *Ex post* it may be used to shed light on (non-)cartel membership. For instance, a seller claiming to have been an outsider to the cartel may be asked to explain why it lost market share during the collusive period. As there are always multiple explanations for observed firm conduct, scrutinizing market share dynamics may not deliver conclusive evidence in either of these cases. Yet, as the analysis of the European truck cartel illustrates, it can be sufficiently telling to serve as collusive marker.

[31] Scania appealed the decision, but this appeal was dismissed by the General Court in 2022.

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