How Costly Are Cartels?[*]

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Abstract

We study the cost of cartels in an oligopoly model with heterogeneous firms, endogenous markups, and collusion. Cartels can amplify or dampen misallocation, by charging supracompetitive markups and reallocating demand towards non-colluding firms. We find that standard competitive oligopoly models understate the cost of markups under reasonable values for the intensity of collusion and cartel composition configurations. Using French micro data, our baseline calibration suggests that breaking down cartels would increase aggregate productivity by 1.1% and welfare by 2%. These numbers shed light on the aggregate importance of collusion.

Keywords: Competition, cartels, collusion, productivity, welfare, misallocation

JEL classifications: D43, K21, L13, L41, O47

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> *The idea that cartels might reduce industry productivity by misallocating production from high to low productivity producers is as old as Adam. While the idea has stood the test of time, it has done little else.*
>
> Bridgman et al. (2015)

1 Introduction

Mounting evidence suggests that the cost of markups is both large and rapidly growing (Edmond et al., 2022; Baqaee and Farhi, 2020). There is far less agreement, however, on the sources and economic importance of the distortions generating these markups. We explore this issue by studying collusion, one micro origin of competition distortion, and tracing its aggregate impact on the economy.[1]

The lack of quantitative work on cartels in macroeconomics is unlikely to be due to lack of importance or interest.[2] The variety of cartel arrangements requires a macroeconomic framework rich enough to accommodate collusive firms of varying sizes, markups, and overcharges alongside firms who behave competitively. The goal of this paper is to propose a flexible yet parsimonious approach to quantify the macroeconomic cost of cartels. As a result, our model allows us to integrate the empirical cartel literature with recent macroeconomic studies on the productivity and welfare costs of markups, and, in particular, to disentangle markups stemming from the unilateral exercise of market power (Edmond et al., 2022; Baqaee and Farhi, 2020) from overcharges arising from collusion between firms.

Specifically, we extend Atkeson and Burstein (2008)'s static heterogenous-firm model with oligopolistic competition by introducing collusive behaviors,[3] which we microfound using the tractable cross-ownership framework of O'brien and Salop (1999). Heterogenous markups arise endogenously in the model as more productive firms have a large market share, thereby facing a lower demand elasticity and allowing them to charge higher markups in equilibrium.[4] Cartel members deviate from own-profit maximization, as they internalize some of their impact on the

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[1] From the infamous 1920s Phoebus cartel, a landmark case of planned obsolescence with light bulbs engineered to be shorter-lived, to vitamin or car glass cartels, cooperation between competing firms on the prices charged to customers is typically forbidden by antitrust authorities. We focus on horizontal cartels that affect prices.

[2] From a theoretical standpoint, cartels may have little effect on the economy if competitive forces —incentives to defect from the collusive agreement (Stigler, 1964)—are strong enough to make cartels unstable and irremediably short-lived. In contrast, the recent empirical literature has shown that cartels are long-lasting (Levenstein and Suslow, 2006; Hyytinen et al., 2018) and that "some forms of collusion are likely to be prevalent in many industries" (Asker and Nocke, 2021), which we also show in our data.

[3] We use moments on the empirical composition of cartels to discipline the model. A comprehensive theory of cartel formation is beyond the scope of the paper.

[4] This is inefficient as more productive firms are "too small" because of their market power.

profits of other cartel members. In equilibrium, cartel members' demand elasticities thus depend on their own market shares as well as the market share of other cartel members weighted by an intensity of collusion parameter. As a result, cartel members face a lower demand elasticity and charge supracompetitive markups, i.e., overcharges,[5] which affect markup dispersion and the level of the aggregate markup. Importantly, the effect of cartels on aggregate productivity is ambiguous: while supracompetitive markups entail an output drop of colluding firms, they also trigger market share reallocations towards non-colluding firms. Depending on the composition of cartels, productivity may increase or decrease.

We calibrate our model to French data to match moments such as the level of the aggregate markup, the amount of sales concentration, the relationship between market shares and markups, and, perhaps most importantly, the amount of overcharge induced by cartels. Indeed, the degree of overcharge helps us pin down the parameter governing the intensity of collusion and to conduct policy-relevant counterfactual exercises —as we drive the amount of overcharge from positive values to zero.[6] As we compute the cost of cartels with respect to a counterfactual competitive economy and rely on a moment commonly used by antitrust authorities across OECD countries to assess the damage cartels inflict on the economy, our framework complements their methodologies.[7]

As our framework naturally nests the Atkeson and Burstein (2008) model when the intensity of collusion is set to zero, we show that a calibrated *competitive* version of the model may indeed generate less markup dispersion, and thus less misallocation, than a model explicitly accounting for collusion. Interestingly, this is the case under different cartel composition configurations —from cartels being made up of the least efficient firms to cartels being all-inclusive —and for reasonable values of the collusion intensity.[8] This points to competitive oligopoly models with

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[5] Cartels differ from horizontal mergers in which cost synergies might increase the productivity of the firms involved in the merger and dominate the increase in market power as in the classical trade-off model of Williamson (1968).

[6] An intuitive screen can be derived from the model, which could be used to detect cartels and provide additional evidence regarding the value of the intensity of collusion parameter. Measurement error notwithstanding, given the absence of firm-level prices to estimate the level of markups over our time period (Bond et al., 2021; De Ridder et al., 2022), our intensity of collusion estimated using the screen is, reassuringly, relatively close to our benchmark value. See Section 6.1.1 for additional details.

[7] Antitrust authorities typically assume a target for the cartel overcharge equal to 10% (OECD, 2014), and, in addition, make other assumptions on the duration of the anticompetitive practice and the extent to which sales on the relevant market were affected. More recent studies suggest an even slightly larger cartel overcharge (Boyer and Kotchoni, 2015). We rely on a conservative target of 10% for our baseline results to closely match antitrust authorities' target and test the robustness of our analysis to using a different value.

[8] The exception being when cartel members are randomly selected from the top of the productivity distribution *and* when the intensity of collusion is sufficiently small. When the intensity of collusion is high enough, collusion amplifies the productivity cost of markups. In both cases, this

size-related markup dispersion à la Edmond et al. (2022) potentially understating the cost of markups.

Our calibrated model with collusion assumes that cartels in cartelized sectors are made up of top producers, instead of being made up of the least efficient firms, being all-inclusive, or being amongst the top firms. First, this is motivated by our empirical evidence that cartel members tend to be much larger in terms of observable firm characteristics and productive than non-cartel members, even within narrowly defined industries. We further show that cartels are made up of relatively homogeneous firms in terms of productivity and sales. While these results are to be interpreted with caution given that colluding firms have been detected by the competition authority, they are nevertheless consistent with recent work on cartel formation choice showing that cartels can be expected to be made up of the largest firms (Bos and Harrington, 2010, 2015). Second, these alternative cartel composition settings are not able to yield reasonable cartel overcharges.

To assess the impact of cartels on aggregate productivity and welfare, we study how these variables change as the intensity of collusion parameter is reduced to zero. We find that aggregate TFP would be 1.1% higher if there were no cartels. Intuitively, because cartel members are the top firms in their industry, breaking them down reduces markups and reallocates demand towards these large producers. This decreases markup dispersion and increases aggregate productivity. Second, our framework also has implications in terms of distance to the efficient allocation, where relative prices are aligned with relative marginal costs. We find that eliminating cartels —thereby reducing the extra amount of markup dispersion —would bring the economy 30% closer to the efficient allocation. This suggests that eliminating cartels can be an effective way of improving allocative efficiency. Third, the decrease in the *level* of markups leads to a drop in the aggregate markup, which also has welfare implications. We find that eliminating cartels would lead to a consumption-equivalent welfare gain of about 2%. Finally, we find that the productivity (welfare) cost of markups computed with respect to the efficient allocation is 70% (58%) higher in our calibrated oligopoly model with collusion than in a calibrated competitive oligopoly model. In other words, although both types of models are calibrated to the same data, our oligopoly version with collusion generates relatively more misallocation to start with, thereby increasing the cost of markups highlighted in the recent literature (Edmond et al., 2022).[9]

These numbers challenge the received wisdom that the economic cost of distortions to competition might be low, as they are one order of magnitude higher than

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configuration does not yield realistic cartel overcharges.

[9] Compared to their oligopoly model, ours abstracts from entry and exit. We later discuss how this may affect our results.

the estimate provided by Harberger (1954). We show that our model can reproduce Harberger's estimate when we instead assume a sectoral version of the model with no markup dispersion across firms within industries, or when the demand elasticities are close to unity —as he assumed using sectoral data. Intuitively, this is because larger elasticities of substitution generate more markup dispersion, as does relying on disaggregated data, as also recently shown by Baqaee and Farhi (2020).

Breaking down cartels would also increase competition through a second, indirect channel. Indeed, the presence of a cartel allows non-cartel members to increase their markups and prices as the prices of cartel members serve as an umbrella. We find that this umbrella pricing effect dampens the aggregate gains to productivity and welfare but that the effect is quantitatively small: not allowing non-cartel members to adjust their markups downwards would lead to a 1.14% increase in aggregate productivity instead of 1.11% for our benchmark results. We also study the welfare gains of competition policy at the intensive margin, i.e., cartel members respond to more vigilant antitrust scrutiny by reducing their collusion intensities.[10] We find that the intensive margin of cartels is important too. A decrease in the collusion intensity parameter of approximately 50% still generates gains to aggregate productivity and welfare equal to 0.5% and 0.85%, respectively.

Our results are robust to changing the cartel overcharge target, to allowing the model to match a lower or higher aggregate markup to account for uncertainty regarding this target, to allowing firms to compete à la Bertrand and to allowing the intensity of collusion to differ across cartels. These experiments continue to predict sizable gains from breaking down cartels.

We have stressed that markup dispersion in the model is size-related. There are, however, alternative sources of market power and misallocation not necessarily related to firm size, such as geography. As a consequence, we note that a limitation of the cost of cartels that we unveil may be due to the fact that cartels may affect misallocation by charging different markups across locations, for instance. Furthermore, cartels, by increasing profits, may generate entry of firms or perhaps even boost innovation. With this in mind, our quantitative results nevertheless suggest that the static cost of cartels may be important.

Related literature. Misallocation of factors of production is an important source of productivity loss (Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009). We focus on markup dispersion as a source of misallocation, which Edmond et al. (2022) and Baqaee and Farhi (2020) also analyze in important contributions. Our paper differs from theirs in that we focus on a specific type of competition distortion.

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[10] For instance, this might be the case if the threat of increased fines if the cartel is detected by antitrust authorities is credible.

Moreover, our main exercise consists in quantifying the gains of going from the cartel allocation to the competitive one, which remains inefficient. While it might be hard to implement policies that fully eliminate markup dispersion, eliminating the extra dispersion caused by the presence of cartels is arguably more easily attainable through competition policy.[11] For these reasons, we view our contribution and that of Edmond et al. (2022) and Baqaee and Farhi (2020) as complementary. In a different vein, Brooks et al. (2021) develop a screen for identifying noncompetitive behaviors in China's manufacturing clusters. They find that while firms in clusters charge higher markups, markup dispersion goes down in the industry. The latter effect dominates the former in their welfare calculation, increasing welfare. Our work is different in several regards. While our microfounded framework naturally nests their ad hoc screen, we study the whole economy rather than manufacturing, quantify a model based on actual anticompetitive behaviors and find negative effects of cartels on markup dispersion. Our model rationalizes this seemingly conflicting result: we show that it depends on the composition of cartels and the intensity of collusion.

Our work also relates to recent influential papers that document the rise of markups (De Loecker et al., 2020; De Loecker and Eeckhout, 2018) and link changes in market concentration to changes in the labor share (Autor et al., 2020; De Loecker et al., 2021). Although we focus on quantifying the gains from breaking down cartels, our framework also has implications in terms of the relationship between competition and market power over time and across markets. Gutiérrez and Philippon (2018) argue that laxer antitrust enforcement in the US is behind the larger increase in concentration observed in the US compared to Europe. If lax antitrust enforcement allows cartels to develop and prosper, this would reduce competition within sectors, increase the market power of all firms, thereby driving up the aggregate markup and depressing the aggregate labor share. Our findings are in line with those of Vaziri (2022) who finds that stronger antitrust policies that help fight aggressive strategies (i.e., aggressive pricing, killer acquisitions etc.) increase productivity growth and welfare.

Our microfoundation of collusion builds on cross-ownership models à la O'brien and Salop (1999) and recently revived by Azar et al. (2018) and in contemporaneous quantitative work such as Ederer and Pellegrino (2021). Our approach differs, however, as we embed collusion within the oligopoly model of Atkeson and Burstein (2008), which allows us to center our analysis on the aggregate productivity effect of collusion and show how standard competitive oligopoly models may understate

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[11] Our results further provide a mechanism why measures that increase competition improve productivity as Buccirossi et al. (2013) document for 22 industries in twelve OECD countries over 1995 to 2005.

the extent of misallocation.

Our work also builds on recent theoretical and empirical advances on cartels. Bos and Harrington (2010) study cartel formation with heterogeneous firms. They show that larger firms have a strong incentive to form a cartel when they are patient enough, and that smaller firms can increase their prices as the larger firms' prices serve as an umbrella. We provide evidence that discovered cartel members are more productive and are larger than non-cartel members in their industry. The empirical study of cartels and their impact on productivity is limited by the fact that secret agreements are, by definition, hard to observe.[12] It is possible, however, to focus on specific cartels operating in particular industries. Bridgman et al. (2015) estimate that the New Deal sugar cartel tremendously decreased productivity through reallocation of production towards low productivity firms in the beet and cane industries. Asker et al. (2019) focus on the oil industry and quantify the role of market power in generating misallocation. Our paper instead connects the cartel and macroeconomics literature by looking at the productivity and welfare implications of cartels from a macroeconomic perspective.

The paper proceeds as follows. Section 2 details our data. Section 3 introduces the model. Section 4 provides more information on the quantification of the model. Our results are presented in Section 5 and we discuss several aspects of our analysis and robustness experiments in Section 6. Section 7 concludes.

2 Data

In this section, we describe our data and certain characteristics of cartels.

2.1 Antitrust decisions

The French Competition Authority (ADLC) is primarily in charge of investigating and fining companies operating on the French market that are found guilty of engaging in any form of anticompetitive practice, i.e., abuse of dominant position, collusion or predatory pricing.[13] We focus on collusion between firms so that anticompetitive practices will refer to collusion hereafter. Collusive behaviors might involve firms trading information on their prices, imposing standard form contracts, enforcing barriers to entry, imposing exclusive or selective distribution agreements,

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[12] Levenstein and Suslow (2006) survey the literature on cartels. Most papers study the impact of cartels on prices or the determinants of cartels' success (Levenstein and Suslow, 2011). Some papers instead study the impact of cartels on welfare, such as Röller and Steen (2006) in the context of the Norwegian cement industry.

[13] The variety of possible collusive arrangements, which include price fixing, production limitations or market sharing, are recognized by Article 101 of the Treaty on the Functioning of the European Union.

market sharing, purposely stepping down from calls for bids, or a combination of the above.

We assemble a firm-level dataset on French cartels over the period 1994-2007, using the written reports of all the antitrust decisions taken by the ADLC over the last decades. Our database summarizes information contained in the investigation and decisions files published in French on the ADLC website. Crucially, the PDF files contain the name of the firms that are fined for engaging in anticompetitive practices.[14] We also retrieve information on the amount of the fine, the type of anticompetitive practice, the duration of the practice, the cause of breakup, the year the verdict is returned and the starting year of the investigation. We then use the companies' names and sales to recover their unique national identification code ("SIREN" code) given by the French National Institute of Statistics and Economic Studies (INSEE). This allows us to match our database to other firm-level production datasets. More details on the construction of the database can be found in Appendix A.[15]

Because our analysis focuses on a single country and because information on market shares of foreign firms on the French market cannot be recovered, international cartels are not included in our data. These cross-country cartels are usually investigated by the European Commission and its Directorate General for Competition (DG Comp), which deals with cases affecting multiple European member states. Given that these private international cartels are typically "the largest, most injurious, and most difficult to prosecute of all price-fixing violations" (Connor, 2020),[16] the estimates we provide based on national cartels will likely *underestimate* the impact of collusion. We eliminate from our dataset cases where single firms were fined for behaving anticompetitively. This is the case if firms abused their dominant position or are repeat offenders, for example. Our final dataset on cartels contains 174 cartels and more than a thousand firms before merging.

2.2 Administrative data

We match our database on anti-competitive firms with firm-level data for France, using the firms' identification number. The datasets that we use contain the uni-

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[14] We rely on automatic textual analysis and manual checks to retrieve information on the identity of the firms fined by the antitrust body and then merge it to the other datasets. We do not use information on firms notified by an injunction: often, these firms are fined later on by the ADLC and thus appear in our database.

[15] The number of decisions per year and the number of firms involved are reported in fig. A1 and fig. A2. Figure A3 displays a representative report from the ADLC (decision file 17d20). Figure A4 shows that information on the duration of cartel can also be found in these reports, as well as information on the type of infringement (fig. A5).

[16] As Connor (2020) explains, "private cartels are those that are not protected by government sovereignty or by international treaties, like the Organization of Oil Exporting Countries (OPEC)".

verse of French firms over the period 1994-2007. These datasets contain the balance sheets and income statements of all French firms. We keep both large and smaller firms which corresponds to two different tax regimes, the Regime of Normal Real Profits (BRN) and the Simplified Regime for the Self-Employed (RSI), respectively. BRN contains firms with annual sales above 763K euros (230K euros for services) whereas smaller firms included in RSI sell at least 76.3K euros (but less than 763K euros) a year and more than 27K euros for services. However, BRN is the most relevant data source given that in 2003, BRN firms' sales share in total sales was 94.3% and is constant over time. This data source has been used in previous studies, for instance in Di Giovanni et al. (2014), and we refer to their paper for more information. Importantly, these exhaustive databases allow us to recover a firm's market share and other variables we use in our empirical analysis. More information on the variables we use can be found in Appendix A.

2.3 Characteristics of cartels

2.3.1 Cartel duration, size, and activities

The average duration of a cartel is about 4.5 years (Table 1), which is close to the average duration reported in Monnier-Schlumberger and Hutin (2016) who report an average duration of five years for their sample of discovered French cartels observed over the period 2003-2015. This also matches the average duration of cartels summarized in Levenstein and Suslow (2006) for a wide range of studies. Our median duration is about 3 years, which is also consistent with what Monnier-Schlumberger and Hutin (2016) report (3.8 years).[17]

The average number of firms per cartel is 6 and the median is 4. While there are extremely large cartels made up of more than 70 firms, this is not the norm as the standard deviation is equal to 7. Combe and Monnier (2012) report an average (median) number of firms per cartel of 7.7 (5), while Monnier-Schlumberger and Hutin (2016) report an average number of cartel members of 10.

We further report a few statistics on the types of cartels. Most firms that are part of a cartel share confidential information, rig procurement auctions, and fix their prices. Communicating seems to be a pervasive feature of cartels. As Asker and Nocke (2021) argue, "across the heterogeneity of cartel forms, a relatively common feature, empirically, of coordinated activity that seems uncontroversially anticompetitive is communication". They also share their customers and their market shares, which has been found to be the type of practice that allows cartels to sustain their illegal activities for a long time (Combe and Monnier, 2012; Levenstein, 2006).

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[17] Combe and Monnier (2012) find that the average (median) duration of cartels is 7 (6) years for their sample of European cartels detected and fined by the European Commission over 1969-2009.

Table 1: Characteristics of Cartels

	Mean (1)	Std. Dev. (2)	Median (3)	Min (4)	Max (5)
Duration (years)	4.49	5.74	3	1	47
# Firms per cartel	6.3	7.4	4	2	76
Price fixing	0.35	0.48	0	0	1
Market allocation	0.29	0.46	0	0	1
Production quotas	0.04	0.2	0	0	1
Information sharing	0.59	0.49	1	0	1
Repeat offender	0.08	0.27	0	0	1
Bid rigging	0.40	0.49	0	0	1
Dominant leader	0.04	0.2	0	0	1
Abuse of dominant position	0.03	0.18	0	0	1
Guaranteed buy-backs	0.07	0.25	0	0	1
Exclusive dealing contracts	0.18	0.38	0	0	1
# Cartels			174		
# Cartel members			1,037		

Notes: The table displays some important characteristics of cartels, using the firm-level database detailed in Appendix A.2. We only consider the decision files involving at least two firms over the period 1994-2007. The duration of the cartel is expressed in years but can be less than a year, in which case it is rounded to one year. The variables (price fixing, market allocation, etc.) that take their values between 0 and 1 are dummy variables.

2.3.2 Cartels across sectors

Cartels are prevalent in France over the period 1994-2007 (Table 2).[18] Detected cartels operate in the manufacturing sector but also in the construction, wholesale and retail and transportation sectors. This confirms findings that cartels affect intermediate good sectors, as well as other sectors such as services (Monnier-Schlumberger and Hutin, 2016). Columns 5 and 6 display the average number of anticompetitive firms in each sector over the period 1994-2007. There are only three sectors in which no firm was convicted, namely the agricultural, electricity, and education sectors, which account for 4.8% of total value-added. Table A1 in the Appendix shows that cartels can be found in a variety of sectors when looking at a given cross-section.

This finding adds further empirical support to the fact that cartels operate across a wide range of industries and sectors.[19]

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[18] The number of cartel members reported may be equal to one because some cartel members were not matched in the administrative data.

[19] For instance, Levenstein and Suslow (2006) report cartels spanning the beer, bromine, cement, coal, diamonds, electrical equipment, ocean shipping, oil, parcel post, potash, railroad, rayon, steel, sugar and tea industries.

Table 2: Cartels by Sector

NAF (1)	Sector (2)	Sales Share (3)	VA Share (4)	# Cartels (5)	# Colluding Firms (6)
01-05	Agriculture, hunting, forestry, fishing	0.0013	0.0019		
10-14	Mining and quarrying	0.0033	0.0047	1	2
15-16	Food products, beverages and tobacco	0.0553	0.0534	3	19
17-19	Textiles, leather and footwear	0.0136	0.0143	1	1
20	Wood and wood products	0.0048	0.0051	1	8
21-22	Pulp, paper, publishing and printing	0.0227	0.0260	1	4
23	Coke	0.0237	0.0260	1	4
24	Chemicals	0.0435	0.0403	2	9
25	Rubber and plastics	0.0151	0.0169	2	3
26	Other non-metallic mineral prod.	0.0109	0.0133	3	12
27-28	Basic metals and fabricated metal prod.	0.0362	0.0412	2	9
29	Machinery and equipment n.e.c.	0.0250	0.0265	2	7
30-33	Electrical and optical equipment	0.0378	0.0410	2	4
34-35	Transport equipment	0.0533	0.0406	1	2
36-37	Other manufacturing n.e.c	0.0102	0.0107	2	3
40-41	Electricity, gas and water supply	0.0285	0.0428		
45	Construction	0.0596	0.0758	7	42
50-52	Wholesale and retail	0.3518	0.1872	11	69
55	Hotels and restaurants	0.0198	0.0310	1	3
60-63	Transport and storage	0.0472	0.0552	5	27
64	Post and telecommunications	0.0236	0.0503	1	2
70	Real estate activities	0.0140	0.0222	2	2
71-74	Renting and business activities	0.0722	0.1246	8	16
80	Education	0.0016	0.0029		
85	Health and social work	0.0078	0.0157	1	9
90-93	Other service activities	0.0173	0.0304	3	5

Notes: The sales share column represents sector-level sales in total sales over the period 1994-2007. The VA share column represents sector-level value-added in total value-added over the period 1994-2007. The values displayed for the number of cartels and colluding firms in columns (5) and (6) are averages over the period 1994-2007.

3 Model

We build a static, closed-economy, model in which heterogeneous firms choose their markups endogenously along the lines of Atkeson and Burstein (2008), and where cartels coexist with competitive firms. The model allows for both Cournot and Bertrand competition. The economy consists of a continuum of sectors in which a *finite* number of firms compete with each other. In equilibrium, firms' endogenous markups increase with their market share. We abstract from free entry.

We adopt Harrington Jr (2017)'s definition of collusive behavior: "collusion is when firms in a market *coordinate* their behavior for the purpose of producing a *supracompetitive outcome*" (Harrington Jr, 2017, p.1, emphasis in original). Collusion affects the extent to which firms internalize the impact of their production and pricing decisions on the sectoral output and price level. We micro-found collusion by building on cross-ownership models (O'brien and Salop, 1999), which produce similar competition distortions.[20] The most attractive feature of our framework is its tractability: it nests several modes of collusion depending on the value of a single parameter. This collusion intensity parameter κ captures what is arguably the most

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[20] Gilo et al. (2006) and de Haas and Paha (2016) study how common ownership affects collusion.

important feature of cartels, cartel overcharges, which distort price schedules and affect aggregate productivity and welfare.

3.1 Environment

An infinitely-lived representative household maximizes a time-separable utility

$$\mathbb{E}\sum_{t=0}^{\infty}\beta^{t}\mathcal{U}\left(c_t, 1-l_t\right) \tag{1}$$

The first-order conditions for the household are standard and yield the familiar intra-temporal tradeoff between consumption and leisure: $-\frac{\mathcal{U}_{l,t}}{\mathcal{U}_{c,t}} = \frac{W_t}{P_t}$.

3.1.1 Market structure

The production side of the economy consists of a continuum of sectors indexed by $s \in [0,1]$. Final consumption c is produced by a competitive firm that combines the outputs from all the sectors y_s with a CES technology with elasticity η:

$$c = \left[\int_0^1 y_s^{\frac{\eta-1}{\eta}}\, ds\right]^{\frac{\eta}{\eta-1}} \tag{2}$$

The inverse demand function for each intermediate output from sector s is given by:

$$\frac{P_s}{P} = \left(\frac{y_s}{c}\right)^{-\frac{1}{\eta}} \tag{3}$$

where P, the price index for final consumption representing the “true cost of living”, is a function of the sectoral prices:

$$P = \left[\int_0^1 P_s^{1-\eta} ds\right]^{\frac{1}{1-\eta}} \tag{4}$$

Each sector is populated by a finite number of firms K_s indexed by k. Because each firm has a non-zero measure, it is therefore “large in the small but small in the large” (Neary, 2003), i.e., firms are small with respect to the economy but large in their own sector. The output of sector s is a composite of the firms’ outputs, combined with a CES technology with elasticity parameter ρ:[21]

$$y_s = \left[\sum_{k=1}^{K_s}\left(q_{sk}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{5}$$

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[21] Goods are imperfect substitutes, $\rho < \infty$, and more substitutable within than between sectors, $1 < \eta < \rho$.

The inverse demand functions within each sector are given by:

$$\frac{P_{sk}}{P_s} = \left(\frac{q_{sk}}{y_s}\right)^{-\frac{1}{\rho}} \tag{6}$$

where the price index P_s in sector s is given by

$$P_s = \left[\sum_{k=1}^{K_s} (P_{sk})^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{7}$$

We consider an industry s populated by K_s firms, of which a subset $\mathcal{C}_s$ forms a cartel, with $0 \leq |\mathcal{C}_s| \leq K_s$. For simplicity, we abstract from vertical arrangements and assume that firms form horizontal cartels that do not reach across industries. Moreover, we derive our main results under Cournot competition but our results are qualitatively robust to assuming Bertrand competition as shown in Appendix B.6 and in the robustness section.

3.1.2 Non-cartel members

With linear labor costs and heterogenous productivity z_{si}, any competitive firm that does not belong to the cartel ($i \notin \mathcal{C}_s$) solves the following maximization problem:

$$\max_{q_{si}} \left(P_{si} - \frac{W}{z_{si}}\right) q_{si}, \tag{8}$$

subject to the inverse demand function

$$\left(\frac{P_{si}}{P}\right) = \left(\frac{q_{si}}{y_s}\right)^{-\frac{1}{\rho}} \left(\frac{y_s}{c}\right)^{-\frac{1}{\eta}} \tag{9}$$

Profit-maximization implies that the equilibrium price is a markup μ_{si} over the marginal cost of production, where the markup is pinned down by the idiosyncratic demand elasticity ε_{si} faced by the firm,

$$\begin{aligned} \mu_{si} &= \frac{\varepsilon_{si}(\omega_{si})}{\varepsilon_{si}(\omega_{si}) - 1} \\ \varepsilon_{si}(\omega_{si}) &= \left[\frac{1}{\rho} + \left(\frac{1}{\eta} - \frac{1}{\rho}\right)\omega_{si}\right]^{-1} \end{aligned} \tag{10}$$

where $\omega_{si} := \frac{P_{si} q_{si}}{\sum_{j=1}^{K} P_{sj} q_{sj}}$ is the sectoral revenue share of firm i. Firms with larger equilibrium market shares have more market power and therefore charge higher markups. In particular, the CES demand structure implies that the demand elasticity that each firm faces in equilibrium is a harmonic weighted average of the within and between-elasticities.

3.1.3 Cartel members

Collusion distorts firms' profit incentives. Instead of maximizing their own profits independently, members of the same cartel internalize that their decision impacts the other cartel members. The distorted objective function for cartel member k takes the following form:

$$\pi_k^{\mathcal{C}} = \pi_k + \sum_{j \in \mathcal{C} \setminus \{k\}} \kappa_{kj} \pi_j \tag{11}$$

where π_k corresponds to firm k's own profits and the κ_{kj} parameter captures the intensity of collusion. This flexible formulation allows straightforward analytical derivations of collusive behaviors of various intensities and sizes. In addition, it is consistent with micro-foundations that could cover side payments or ringleaders exerting control over the production decisions of other, often smaller, cartel members.[22]

Cartel members therefore solve the following maximization problem:

$$\max_{q_{sk}} \left[\left(P_{sk} - \frac{W}{z_{sk}} \right) q_{sk} + \sum_{j \in \mathcal{C} \setminus \{k\}} \kappa_{kj} \left(P_{sj} - \frac{W}{z_{sj}} \right) q_{sj} \right], \quad \forall k \in \mathcal{C}_s \tag{12}$$

subject to

$$\left(\frac{P_{sk}}{P} \right) = \left(\frac{q_{sk}}{y_s} \right)^{-\frac{1}{\rho}} \left(\frac{y_s}{c} \right)^{-\frac{1}{\eta}} \tag{13}$$

Markups take a similar form as in eq. (10) but collusion weakens competition, generating demand elasticities $\varepsilon_{sk}^{\mathcal{C}}$ for cartel members:

$$\varepsilon_{sk}^{\mathcal{C}} \left(\omega_{sk} \right) = \left[\frac{1}{\rho} + \left(\frac{1}{\eta} - \frac{1}{\rho} \right) \left(\omega_{sk} + \sum_{j \in \mathcal{C} \setminus \{k\}} \kappa_{kj} \omega_{sj} \right) \right]^{-1} \tag{14}$$

One observation is noteworthy. Cartels do not affect fundamentals - firms' productivity - but distort cartel members' production decisions, as they partially internalize the effect of their own production decisions on other members' profits. This can be seen from eq. (14) in which the market share of other cartel members lowers

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[22] Let β_{jl} denote the share of firm j's operational profits promised as a side-payment to firm l. The financial profits accruing to firm l's shareholders then correspond to the portfolio $\pi^l = \sum_j \beta_{jl} \pi_j$. If firm k is under the influence of other members of the cartel, then the distorted objective function of its managers becomes $\tilde{\pi}_k = \sum_{l \in \mathcal{C}} \gamma_{kl} \pi^l = \sum_l \gamma_{kl} \sum_j \beta_{jl} \pi_j$ where γ_{kl} denotes firm l's control over firm k's operational decisions, that forces firm k's managers to internalize the impact of their decisions on firm l's profits. For the distinction between ownership and control, see Shleifer and Vishny (1997). See O'brien and Salop (1999), Azar et al. (2018), Azar and Vives (2021), and Ederer and Pellegrino (2021) for related formulations in the common ownership literature. See Appendix B for details.

cartel members' own demand elasticity, allowing them to charge higher markups.

3.1.4 Types of collusion

The extent to which colluding firms internalize part of the effect of their decision on the other cartel members' profits depends on the profit weights κ_{kj}. Importantly, our model nests several cases of interest.[23]

Benchmark competitive economy. When all the collusion parameters κ_{kj} are set to zero, there are no cartels and the model boils down to a competitive Nash-Cournot model with heterogeneous firms (Atkeson and Burstein, 2008). In this case, firms' markups are given by eq. (10), with more productive firms charging higher markups. This is the main counterfactual allocation we consider to compute the aggregate gains from eliminating cartels.

Cartels with symmetric collusion. The second case we consider is that of imperfect collusion where cartel members partially internalize each other's behavior in a symmetric fashion.[24,25] Markups are given by

$$\mu_{sk}^{\mathcal{C}} = \left[\frac{\rho-1}{\rho} + \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho}\right)\left(\omega_{sk} + \kappa \sum_{j\in\mathcal{C}\setminus\{k\}} \omega_{sj}\right)\right]^{-1} \tag{15}$$

This is a sales-weighted harmonic average of the within- and between- markups as in the benchmark case, except that the weight is augmented to reflect the market power of the other firms in the cartel. This effect is more pronounced as the collusion intensity κ increases.

Cartels with full collusion. The case where the profit weights are equal to unity boils down to full collusion where firms maximize their joint profits and equally weigh all cartel members' profits. In this case, the markup of cartel member k is:

$$\mu_{sk}^{\mathcal{C}} = \left[\frac{\rho-1}{\rho} + \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho}\right) \sum_{j\in\mathcal{C}} \omega_{sj}\right]^{-1} \tag{16}$$

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[23] The micro-founded model in the appendix details configurations that support the cases detailed below.

[24] In our micro-founded model, this is the case when firms' ownership shares or influence are constant across different firms. See Appendix B.1 for more details.

[25] This is the case considered by Brooks et al. (2021) who study how Chinese industrial clusters affect competition.

All colluding firms that belong to cartel $\mathcal{C}$ charge the same markup that is governed by the combined market share $\sum_{j\in\mathcal{C}}\omega_{sj}$. This *reduces* markup dispersion for firms within the cartel. However, markup dispersion at the sectoral level might increase depending on the exact composition of the cartel and the reaction of non-cartel members.

3.2 How does collusion distort the market structure?

3.2.1 Collusion and markups

Consider transitioning from the benchmark competitive equilibrium to a collusive equilibrium with a small collusive intensity $\Delta\kappa$. For firm k in the cartel, the log change in markups at the first order is

$$\hat{\mu}^{\mathcal{C}}_{sk} = \underbrace{\Upsilon_{sk}\hat{P}_s}_{\text{Umbrella Pricing}} + \underbrace{\frac{1}{\rho-1}\frac{\Upsilon_{sk}}{\omega_{sk}}\left(\omega_{s\mathcal{C}}-\omega_{sk}\right)\Delta\kappa}_{\text{Cartel Overcharge}} \tag{17}$$

where $\Upsilon_{sk} := \frac{\omega_{sk}(\rho-1)\left(\frac{1}{\eta}-\frac{1}{\rho}\right)\mu_{sk}}{1+\omega_{sk}(\rho-1)\left(\frac{1}{\eta}-\frac{1}{\rho}\right)\mu_{sk}} \in (0,1)$ represents the elasticity of the firm's own price with respect to the sectoral price index and $\hat{P}_s$ is the percentage change in the sectoral price index. The first term is common to all firms in the sector, whether they are part of the cartel or not. It can be interpreted as a form of umbrella pricing, reflecting changes in competition. The second term is specific to cartel members and can be interpreted as the cartel overcharge. The overcharge varies across firms in the cartel and is increasing along both the extensive margin of collusion, i.e. the total market share controlled by the cartel $\omega_{s\mathcal{C}}$ and the intensive margin $\Delta\kappa$.

Proposition 1 (Prices and Markups under Collusion)**.** *Starting from the competitive equilibrium, symmetric collusion i) increases the sectoral price index and ii) increases the markups of all firms. In particular, iii) for cartel members, the markup increase declines with firm size iv) while for non-cartel members, the markup increase increases with firm size.*

Proof. See Appendix B. □

Under symmetric collusion, the overcharge tends to be larger for smaller cartel members.[26] Moreover, collusion entails an increase in the markups of *all* firms, relative to the competitive Nash-Cournot equilibrium. This is because the introduction

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[26] This feature follows directly in our framework from the simplifying assumption that the collusion intensity κ is the same across cartel. Alternatively, one can consider arrangements with varying collusion intensity, or, parsimoniously, back-out the firm-specific collusion intensities that deliver the same overcharge for all cartel members, as derived in Appendix B.4.

of collusion generates an increase in the sectoral price index, which in turn increases the demand of non-cartel members. This allows them to gain market shares and charge higher markups. The framework therefore features an umbrella pricing effect, whereby all firms are able to increase their markups. This leads to an increase in the level of the aggregate markup.

Corollary 1 (Intensive and Extensive Margins of Collusion)**.** *Market distortions arising from collusion are larger i) the more intense the collusion $\Delta\kappa$ and ii) the larger the market share controlled by the cartel. In particular, the sectoral price increase is*

$$\hat{P}_s = \frac{1}{\rho-1}\frac{1}{1-\sum_k \omega_{sk}\Upsilon_{sk}} \sum_{k\in\mathcal{C}} \Upsilon_{sk}\left(\omega_{s\mathcal{C}}-\omega_{sk}\right)\Delta\kappa \tag{18}$$

This intuitive result illustrates that both the intensive and extensive margins of the cartel are at play. Equation (18) entails that both an increase in the collusion intensity $\Delta\kappa$ and a larger market share controlled by the cartel $\omega_{s\mathcal{C}}$ lead to a higher price index in the sector. The latter directly echoes theoretical findings on heterogeneous cartels.[27]

Cartel members charge higher markups than they would in a competitive equilibrium, resulting in a price increase and market share reallocations that also affect firms who are not part of the cartel:[28]

Corollary 2 (Market Shares under Collusion)**.** *Non-cartel members all gain market shares. Among cartel members, the evolution of market shares depends on the composition of the cartel. In particular:*

$$\begin{cases} \hat{\omega}_{sk} = (\rho-1)\left(1-\Upsilon_{sk}\right)\hat{P}_s \\ \hat{\omega}_{sk}^{\mathcal{C}} = (\rho-1)\left(1-\Upsilon_{sk}\right)\hat{P}_s - \frac{\Upsilon_{sk}}{\omega_{sk}}\left(\omega_{s\mathcal{C}}-\omega_{sk}\right)\Delta\kappa \end{cases} \tag{19}$$

Non-colluding firms do not cut their quantities and let their prices rise through the umbrella pricing mechanism, but less than the full magnitude of the sectoral price increase —see Appendix B. Given the nested CES demand structure, this allows them to gain market shares.

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[27] See Theorem 3 in Bos and Harrington (2010).

[28] Unfortunately, we cannot directly look at systematic changes in concentration and prices in our 4-digit industries before and after cartel breakdowns to provide motivational evidence in favor of this mechanism. First, we do not have firm-level data on prices. Second, market concentration is the market outcome of many different supply and demand forces (Syverson, 2019) and cartel breakdowns might themselves be caused by changes in industry performance. As such, changes in concentration may only partially reveal the role played by cartels. Third, exogenous cartel breakdowns cannot be cleanly inferred from our decision files. Indeed, the cause of the breakdown, which is not always reported, is vague. This does not allow us to rely on exogenous antitrust intervention as a shock to competition to look at how cartels might trigger market share reallocations.

3.2.2 Collusion and productivity

How does collusion affect productivity? It turns out that the effect of cartels is theoretically ambiguous. To see this, observe that the change in sectoral productivity is:[29]

$$\hat{z}_s = \sum_k \omega_{sk} \left(\frac{\mu_s}{\mu_{sk}} - 1 \right) \hat{P}_{sk} + (\rho - 1) \sum_k \omega_{sk} \frac{\mu_s}{\mu_{sk}} \left(\hat{P}_{sk} - \hat{P}_s \right) \tag{20}$$

The impact on productivity can be decomposed into two channels: a direct price effect and a demand reallocation effect. In the absence of markup dispersion, changes in prices would not directly impact sectoral productivity, as $\mu_{sk} = \mu_s$ for all k. In contrast, in the presence of markup dispersion, price increases from high-markup firms reduce sectoral productivity. The second term reflects the change in market shares. If the cartel is made up of top producers with above average markups, demand is redirected towards less productive firms within that sector and, as a result, sectoral productivity decreases. In contrast, a cartel made up of the smallest firms in that sector would redirect demand towards larger, more productive firms, increasing overall productivity, everything else equal. Note that it is possible for aggregate productivity to be at its first-best level in the presence of collusion. This is the case if the economy is fully cartelized, i.e., all sectors are cartelized and cartels include all operating firms, and $\kappa = 1$. In this case, collusion eliminates markup dispersion.[30]

3.3 Aggregate productivity and welfare

The model can be aggregated analytically, which yields a transparent analysis of the impact of distortions on productivity and welfare. In particular, output in this economy can be represented by an aggregate production function $Y = AL$, where A measures aggregate productivity and L is total labor employed in the economy. All aggregate quantities are nested harmonic means of their firm-level counterparts.

3.3.1 Aggregate productivity

Aggregate productivity follows from the first-order condition for the optimal use of labor combined with the labor market clearing condition:

$$A = \left[\int_0^1 \left(\sum_{k=1}^{K_s} \frac{y_{sk}}{Y} z_{sk}^{-1} \right) ds \right]^{-1} \tag{21}$$

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[29] Sector-level productivity z_s is given by $z_s = \left[\sum_{k=1}^{K_s} \left(\frac{\mu_s}{\mu_{sk}} \right)^{\rho} z_{sk}^{\rho-1} \right]^{\frac{1}{\rho-1}}$ and $\mu_s = \frac{P_s}{W/z_s}$ is the sectoral markup.

[30] The effect on welfare may be negative as the aggregate markup always rises with collusion.

Aggregate productivity A is a *quantity*-weighted harmonic average of firm productivity levels. The aggregate markup in the economy, defined as the ratio of the aggregate price to the marginal cost, $\mathcal{M} = \frac{P}{W/A}$, can be expressed as a revenue-weighted harmonic mean of firm-level markups, $\mathcal{M} = \left[\int_0^1 \left(\sum_{k=1}^{K_s} \frac{p_{sk} y_{sk}}{PY} \mu_{sk}^{-1}\right) ds\right]^{-1}$. Alternatively, aggregate productivity can be written in terms of the firm productivity levels and relative markups, $A = \left[\int_0^1 \left(\frac{\mathcal{M}}{\mu_s}\right)^{\eta} z_s^{\eta-1} ds\right]^{\frac{1}{\eta-1}}$.

Our main exercise consists in comparing the aggregate productivity level obtained in the presence of cartels A_{cartel} to the one that would be obtained in the *competitive* Nash-Cournot equilibrium A_{comp}. Any difference between these two productivity levels arises from changes in markup dispersion. This is different from the exercise done by Edmond et al. (2015) and Baqaee and Farhi (2020) who are instead interested in comparing A_{comp} to the efficient productivity level A_{eff} obtained in the *absence* of markup dispersion:[31]

$$A_{\text{eff}} = \left(\int_0^1 \left(\sum_{k=1}^{K_s} z_{sk}^{\rho-1} \right)^{\frac{\eta-1}{\rho-1}} ds \right)^{\frac{1}{\eta-1}} \tag{22}$$

3.3.2 Aggregate welfare

For the model to generate changes in welfare, we consider a standard extension with capital accumulation and elastic labor supply as in the literature (Edmond et al., 2015, 2022). In this case, the level of the aggregate markup acts as a distortionary wedge. Intuitively, an increase in the aggregate markup induced by the cartelization of the economy reduces the aggregate scale of production and decreases the representative consumer's welfare. In the model, the aggregate markup changes as cartels generate market share reallocations and all firms experience a markup increase within cartelized sectors —see Proposition 1. We compute the welfare change in consumption-equivalent units as detailed in Appendix B.7, which takes into account transitional dynamics to the new steady state.

3.4 Competitive oligopoly versus collusion

To better understand how our framework differs from competitive oligopoly models (Atkeson and Burstein, 2008; Edmond et al., 2022), we calibrate a competitive version with $\kappa = 0$ to match the moments described in the next section. We then introduce collusion without changing the values of the baseline parameters except

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[31] In the competitive framework, the economy is not at its first-best level because of markup dispersion arising from firm heterogeneity. Indeed, more productive firms have more market power, produce less than what is socially optimal, which results in a suboptimal allocation.

Table 3: Competitive Oligopoly and Oligopoly with Collusion

Oligopoly model	Competitive	Collusion			
Collusion intensity	$\kappa = 0$				
Cartel's composition		Top producers	Least efficient producers	All-inclusive	Top 10%
	(1)	(2)	(3)	(4)	(5)
		$\kappa = 0.3$			
$A \to A_{\text{eff}}$ (in %)	2.16	2.54	2.16	2.43	1.97
Extra productivity loss (in %)		17.3	0.02	12.4	−9.18
$\mathcal{M}$	1.2	1.21	1.2	1.31	1.2
Cartel overcharge (in %)		4	0.02	17.7	0.52
		$\kappa = 1$			
$A \to A_{\text{eff}}$ (in %)	2.16	3.46	2.18	10	2.49
Extra productivity loss (in %)		59.7	0.6	363.6	15.2
$\mathcal{M}$	1.2	1.217	1.201	1.56	1.206
Cartel overcharge (in %)		9.7	0.07	96	2.69

Notes: Parameter values have been chosen so as to minimize the distance between model and data moments —see Section 4 —for the *competitive* oligopoly model. Columns 2-5 add collusion to the calibrated competitive model: the parameter values do not change except for the intensity of collusion κ and the number of cartel members. The first row displays how eliminating markup dispersion affects aggregate productivity starting from the competitive oligopoly model in column 1 or the oligopoly model with collusion in columns 2-5. The second row shows the change in the distance to the efficient allocation generated by collusion, while the third row displays the level of the aggregate markup. The cartel overcharge reported in the fourth row is defined as the change in prices between the competitive oligopoly model and the one with collusion. Cartel overcharges are the percentage difference in cartel-level markups, which are computed as averages across cartel members in each equilibrium. The overcharge is then defined as the median overcharge across cartels. Column 2 (3) assumes that cartels in cartelized sectors are made up of the most (least) efficient firms. In column 4, cartels in cartelized sectors include all firms, while column 5 assumes that cartels are made up of firms randomly drawn within the top 10% of their productivity distribution. The last four rows are similarly defined and report results for a different value of κ.

for κ. We assign a low and a high value to the collusion intensity by setting $\kappa = 0.3$ as in Brooks et al. (2021) and $\kappa = 1$. Moreover, we set the median number of cartel members to four, consistent with our data. Not all sectors are cartelized. We consider four cases in the model with collusion: either cartels are made up of the top producers in their industry, the least efficient ones, include all firms in cartelized industries (all-inclusive), or are made up of firms randomly selected from the top 10% of each industry's productivity distribution.

The first column of Table 3 shows that the static competitive oligopoly model generates gains from eliminating markup dispersion and reaching the first-best allocation equal to 2.16%. In the first four rows of columns 2 to 5, we assume that $\kappa = 0.3$. When cartels are made up of top producers (column 2), there is more misallocation as demand is reallocated towards less efficient non-colluding firms. The gains from eliminating resource misallocation now reach 2.5%, which represents a 17% increase in misallocation compared to the competitive oligopoly model. The aggregate markup is also higher, at about 1.21, and the cartel overcharge is equal to 4%. In column 3, we instead assume that cartels are made up of the least efficient firms. Collusion marginally increases misallocation in this case. Indeed, cartels reallocate demand towards relatively larger non-colluding firms but this effect is small as colluding firms' influence on the sectoral price index is limited. However, non-colluding firms charge higher markups because of the umbrella pricing mechanism. This second effect slightly dominates, increasing misallocation. The aggregate markup also rises very little compared to column 1. Importantly, the amount of cartel overcharge generated by this model is modest, approaching 0.02%. In column 4, cartels in cartelized sectors are assumed to be all-inclusive. The cost of markups is higher compared to column 1. As in column 3, markup changes within cartelized sectors dominate the reallocation channel, decreasing sectoral productivity. Moreover, it yields a much higher aggregate markup and overcharge, 31% and 18%, respectively. Finally, column 5 assumes that cartels are made up of firms that are randomly selected amongst firms whose productivity draw is in the top 10% of their industry's productivity distribution. Interestingly, this case generates *less* misallocation, as collusion might reallocate market shares towards relatively larger firms that are not cartelized, thereby improving resource allocation. This case, however, yields a very small cartel overcharge (0.5%).

The last four rows consider the same exercise with $\kappa = 1$. The cost of markups rises considerably when cartels are either assumed to be made up of top producers or all-inclusive. In the latter case, the aggregate markup and the cartel overcharge are equal to 1.56 and 96%. Moreover, cartels made up of the least efficient firms generate a very small increase in misallocation (column 3) while column 5 shows that cartels made up of firms in the top 10% of the productivity distribution also increase misallocation. This last case contrasts with the previous case where $\kappa = 0.3$, suggesting that the value of the intensity of collusion affects the amount of misallocation generated in the model for a given cartel composition configuration. Importantly, the amount of overcharge generated by this last case is higher than when $\kappa = 0.3$ but remains small (2.7%).

Overall, although aggregate productivity could in theory reach its first-best level in the presence of collusion, this requires stringent assumptions on the degree of collusion ($\kappa = 1$), on its extent (fully cartelized economy), and on the composition of cartels (all-inclusive). Less extreme configurations show that collusion may amplify or dampen markup dispersion and thus the aggregate productivity cost of markups compared to static competitive oligopoly models. Finally, the amount of overcharge generated depends both on the composition of cartels and on the intensity of collusion.

4 Quantification of the model

We now turn to the description of our calibration strategy. The key parameters determining the extent to which aggregate productivity varies in the presence of cartels are the within and across-sector elasticities of substitution ρ and η, respectively, and the collusion intensity parameter κ. The gap between ρ and η pins down how dispersion in market shares translates into markup dispersion. The extent to

Table 4: Baseline Calibration

Parameter	Interpretation	Value	Method
β	Discount factor	0.96	Assigned
ψ	Labor supply elasticity	0.5	Assigned
δ	Capital depreciation rate	0.1	Assigned
α	Output elasticity of capital	1/3	Assigned
κ	Collusion intensity	0.79	Match data moment
ρ	Substitution within sectors	10.19	Match data moment
η	Substitution between sectors	1.86	Match data moment
ξ	Pareto shape parameter	6.92	Match data moment
σ	Geometric parameter firms	0.003	Match data moment
ζ	Geometric parameter cartel members	0.23	Match data moment

Notes: The parameters are chosen in order to minimize the distance between model and data moments taken from the French micro data in 2007.

which cartel members internalize the effect of their decision on other cartel members depends on the parameter κ, which governs the amount of cartel overcharge. We first describe how we parameterize the model before discussing its fit.

4.1 Parameterization

Assigned parameters. We assume that a time period in the model is one year. The inverse of the Frisch elasticity of labor supply is set to 2. We set the discount factor $\beta = 0.96$ and the depreciation rate of capital $\delta = 0.1$. The output elasticity of capital is $\alpha = 1/3$. These parameters are used to assess the effect of cartels on welfare. The values are reported in Table 4.

Productivity distribution. We assume that the productivity distribution is Pareto. Firms within a sector draw their productivity z from a Pareto distribution with shape parameter ξ. The draws are i.i.d across firms within their sector. This parameter determines the amount of concentration within sectors.

Number of firms per sector. The number of firms per sector is drawn from a geometric distribution with parameter $\sigma \in (0, 1)$ so that the probability of having K_s firms is given by $\sigma(1-\sigma)^{K_s-1}$. The parameter σ pins down the number of firms per sector: for instance, $1/\sigma$ yields the average number of firms.

Number of cartel members. There can only be one cartel per sector s. Not all sectors, however, are cartelized. The number of cartel members is drawn from a geometric distribution with parameter $\zeta \in (0, 1)$ so that the probability of having $K_{\mathcal{C}}$ members is given by $\zeta(1-\zeta)^{K_{\mathcal{C}}-1}$. The parameter ζ pins down the number of cartel members, as the average number of cartel members is $1/\zeta$.

Cartel composition. We provide novel evidence that cartel members are, on average, larger than non-members,[32] and more homogeneous in terms of labor productivity and sales.

Table A2 shows that there exist important size differences between cartel members and non-members by regressing several firm-level observable characteristics on a dummy variable equal to one if firms behave anticompetitively. Specifically, Panel A suggests that anticompetitive firms have about 1900% more sales than competitive firms, have a market share higher by 4 percentage points, have 1150% more employment and 37% higher labor productivity, even within narrowly defined industries. Panel B shows that the results are robust to restricting the analysis to price fixing cartels that represent a minority of the cartel cases in our database —about 47 out of 174 cartels reported in Table 1. We cannot draw definitive conclusions on whether these size differences reflect self-selection into colluding rather than a treatment effect of colluding. However, we point that self-selection might be the most relevant determinant of these cartel premia, as more productive and larger firms are more likely to find it profitable to join a cartel (Bos and Harrington, 2010, 2015).

Table A3 highlights the fact that productivity and sales differences across cartel members are smaller than those across competitive firms in narrowly defined industries.[33] Panel A reports different productivity distribution moments for non-cartel members in their 4-digit industries (columns 1 to 3) and for cartel members within their cartel (column 4 to 6) in 2007. The first three columns echo the findings of Syverson (2004), namely, that there are important productivity differences

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[32] There are two important caveats regarding the numbers we provide. First, unfortunately, the market share of each cartel member is seldom reported in the decision files. We circumvent this issue by calculating the market share of cartel members and the cartel market share using our administrative micro data. The market shares are defined at the 4-digit level —the highest level of disaggregation in our data —for domestic sales. Second, our sample of cartels consists of *discovered* cartels which may not be representative of the latent population of cartels (Harrington Jr and Wei, 2017). Indeed, there might be a myriad of other cartels and colluding companies that go unnoticed —therefore classifying as competitive —while behaving differently from discovered firms. On the one hand, small undetected cartels might break down quickly because they are "bad" at colluding and do not use compensation schemes, for instance —which are typically found to be important in preventing cartel breakdowns (Levenstein and Suslow, 2011). In this case, our numbers would overestimate the size differences between anticompetitive and competitive firms. On the other hand, very large undetected cartel members might be able to go unnoticed because of their capacity to avoid detection and prosecution. This would lead us to underestimate the size differences between cartel members and competitive firms. Although it is not possible to assess the direction of the bias, the theoretical arguments highlighted in Appendix C would point in the direction of a downward bias.

[33] The fact that firms within a cartel are relatively homogeneous, lends empirical credence to the theoretical argument that large cost differences across cartel members might make collusion less easily sustainable (Ivaldi et al., 2007). This is because large firms might be better protected from retaliation in case they deviate from the collusive equilibrium and because large firms might gain relatively more by cheating. Miklos-Thal (2011) provides an interesting theoretical treatment of price fixing with asymmetric participants.

even within narrowly defined industries. For instance, column 1 indicates that the average within-industry interquartile range is about 0.72, which means that firms in the 75th percentile of an industry's productivity distribution are about twice as productive as firms in the 25th percentile. However, this ratio is only 1.4-to-1 across firms within their cartel. Similarly, the average 90-10 and 95-5 percentile productivity ratios across non-cartel members within industries are over 4 to 1 and 7 to 1, respectively. These numbers are 1.7 to one and 1.8 to one, for cartel members. These findings further extend to sales as shown in Panel B.[34]

These findings and additional evidence detailed in Appendix C justify our assumption that whenever a cartel is present in an industry, it is made up of the most productive firms. Alternative cartel composition settings described in Section 3.4 do not generate cartel overcharges consistent with our target detailed below.[35]

4.2 Calibrated parameters

Our model has six parameters that need to be estimated:

$$\theta \equiv \left\{ \kappa, \rho, \eta, \xi, \sigma, \zeta \right\}$$

where θ is the vector of model parameters. These parameters are chosen in order to minimize the following model-data distance function (Acemoglu et al., 2018):

$$\sum_{m=1}^{M} \frac{\left|\text{Moment}_m(\text{Data}) - \text{Moment}_m(\text{Model}, \theta)\right|}{\frac{1}{2}\left(\left|\text{Moment}_m(\text{Data})\right| + \left|\text{Moment}_m(\text{Model}, \theta)\right|\right)}$$

where m denotes each moment and M is the total number of moment targets. We now discuss the moments that help us identify our parameters.

Cartel overcharge. Given that κ determines the amount of cartel overcharge, we choose to match a target for the cartel overcharge of 10% for our baseline results. This is motivated by assumptions used in cartel cases by competition authorities and findings in the industrial organization literature. The OECD guide for helping competition authorities relies on a cartel overcharge of 10% (OECD, 2014).[36,37]

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[34] As a case study, Table A4 illustrates this finding for the manufacture of plastic components for construction industry in which two cartels operated in 2007.

[35] Not only is the all-inclusive configuration too extreme, but it also generates widely varying cartel overcharges depending on the value of κ. Using the other configurations specified in Section 3.4 does not permit matching our cartel overcharge target in our method of moments procedure, as they generate a very small cartel overcharge.

[36] See here.

[37] Levenstein and Suslow (2006) survey studies having looked at the effect of cartels on prices but do not report cartel overcharges. More recently, Asker et al. (2019) find that the OPEC cartel

Moreover, Laborde (2021) finds that the median cartel overcharge is 10%. We also test the robustness of our results to setting the cartel overcharge to 15%. Indeed, Laborde (2019) analyzes cartel overcharge in a sample of cases judged by European national competition authorities and the European Commission. France is the second most represented country with 46 cases out of 239. The author finds that the median cartel overcharge is 15%. Boyer and Kotchoni (2015) further find a median overcharge equal to 13.8% for domestic cartels operating after the 1970s.

Aggregate markup. To help us pin down the elasticity of substitution within sectors, we require that our model matches a given aggregate markup value $\mathcal{M}$. We target a value of $\mathcal{M} = 1.2$, consistent with values reported in the recent literature for France in 2007 (Battiati et al., 2021).[38]

Markups and market shares. The model yields two different equations —depending on whether the sector is cartelized or not (see appendix D) —relating a sector's inverse markup to its Herfindahl-Hirschman index (HHI). Specifically, for non-cartelized sectors, this relationship is given by:

$$\mu_s^{-1} = \frac{\rho - 1}{\rho} - \frac{\frac{\rho}{\eta} - 1}{\rho} \sum_{k=1}^{K_s} \omega_{sk}^2 \tag{23}$$

The slope of this regression is thus informative about η, conditional on ρ. We target a slope parameter $\hat{\beta} = -0.44$ taken from Burstein et al. (2020) for non-cartelized sectors for the sake of consistency.

Distribution of relative sales. To pin down the Pareto shape parameter ξ, we target several moments of the distribution of relative sales. Relative sales are defined as the ratio of sales of a firm in its 4-digit industry to its industry mean and are pooled across all industries in the baseline year. These data moments are reported in column 2 of Table 5. In Panel B, we compute the fraction of firms with relative sales lower than a certain threshold. This distribution is very skewed. For instance, 30.6% of firms have sales that are less than one-tenth of their industry average. However, $1 - 0.805 = 19.5\%$ of firms have sales higher than their industry average and 0.1% of firms have sales higher than fifty times their industry average. In Panel

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overcharge was higher than 700% in the 1980s. See Asker and Nocke (2021) for a recent survey on the effect of cartels on market performance.

[38] In their Table 2, Bighelli et al. (2021) report an average value of the aggregate markup over 2004-2016 of 1.32 and show that the value of the aggregate markup has increased by 7 percentage points over that period. While we cannot infer a value of μ_{agg} for 2007 from these numbers, we will recalibrate the model to match an alternative aggregate markup target of 1.1 and 1.3 in the robustness section.

Table 5: Model Fit

Moments	**Data**	**Model**	**Source**
Panel A.			
Aggregate markup	1.2	1.2	Literature
Cartel overcharge	10%	10%	Literature
Slope parameter	-0.44	-0.44	Burstein et al. (2020)
Median # firms per sector	237	237	French data
Median # members per cartel	4	4	French data
Panel B: Fraction of firms with relative sales			French data
≤ 0.1	0.306	0.23	
≤ 0.5	0.646	0.716	
≤ 1	0.805	0.844	
≤ 2	0.903	0.921	
≤ 5	0.966	0.968	
≤ 10	0.987	0.985	
≤ 50	0.999	0.998	
≤ 100	1.000	1.000	
Panel C: Fraction of sales in firms with relative sales			French data
≤ 0.1	0.012	0.019	
≤ 0.5	0.098	0.122	
≤ 1	0.185	0.185	
≤ 2	0.288	0.261	
≤ 5	0.435	0.384	
≤ 10	0.543	0.495	
≤ 50	0.793	0.769	
≤ 100	0.867	0.877	

Notes: The table reports targeted moments generated by the model and their data counterparts. These moments are detailed in Section 4.2 and Appendix E.

C, we compute the fraction of overall sales accounted for by these firms. The 30.6% smallest firms account for only 1.2% of total sales, while the 0.1% largest firms that sell more than fifty times their industry average account for $1 - 0.793 = 20.7\%$ of France's overall sales in 2007.

Median number of firms per sector. The median number of firms per 4-digit industry is 237 in our administrative data. The parameter σ directly governs the number of firms operating in each sector and we target a median number of firms per sector equal to 237.

Median number of cartel members. The median number of cartel members is four (Table 1). The parameter ζ directly governs the number of cartel members in the economy and we target a median number of members per cartel equal to four.

4.3 Model fit

The bottom rows of Table 4 display the parameter values that we obtain. Given that all parameters affect all moments, we provide a discussion of how each parameter affects each moment in Appendix E.[39]

We note that the elasticity of substitution within sectors $\rho = 10.2$ is higher than that across sectors $\eta = 1.9$, as required by the model. Importantly, we find that the collusion intensity is such that $\kappa = 0.79$. The intensity of collusion needs to be high enough to match the cartel overcharge target given that cartels are not all-inclusive as seen in Table 3.

The model moments are reported in the third column of Table 5. The model matches the aggregate markup, cartel overcharge, slope parameter exactly, as well as the median number of cartel members and median number of firms per sector. Panel B and Panel C show that the model is able to reproduce the amount of concentration in sales observed in the data. For example, the fraction of firms selling less than one-tenth of their industry average is 23% in the model, close to its data counterpart (30.6%). Moreover, these firms account for 1.9% of total sales in our model, when they represent 1.2% of total sales in the data. Our model matches the amount of sales accounted for by firms selling more than their industry average (81%) and more than a hundred times their industry average (about 12%). Table A5 reports a number of non-targeted moments. Our model is able to reproduce relatively well the sales, employment, labor productivity and market share premium of cartel members, as well as the standard deviations of log sales and log employment.

Markup distribution. Table A6 reports moments of the markup distribution implied by the model. We report moments of the unconditional and sectoral markup distribution in our benchmark model (columns 1 and 3) and in a counterfactual competitive economy with no cartels (columns 2 and 4). The table shows that markups are higher and more dispersed within sectors in the presence of cartels (columns 1 and 2). Moreover, markups are also dispersed across sectors as shown in columns 3 and 4.[40] For instance, the ninetieth percentile sectoral markup is 1.29 in the benchmark economy versus 1.26 in the competitive economy. Finally, Figure 1 illustrates the amount of markup dispersion across cartel members in the case where $\kappa = 0$ and $\kappa = 0.79$. As the collusion intensity increases, the distribution of markups shifts to the right and becomes more skewed, increasing misallocation.

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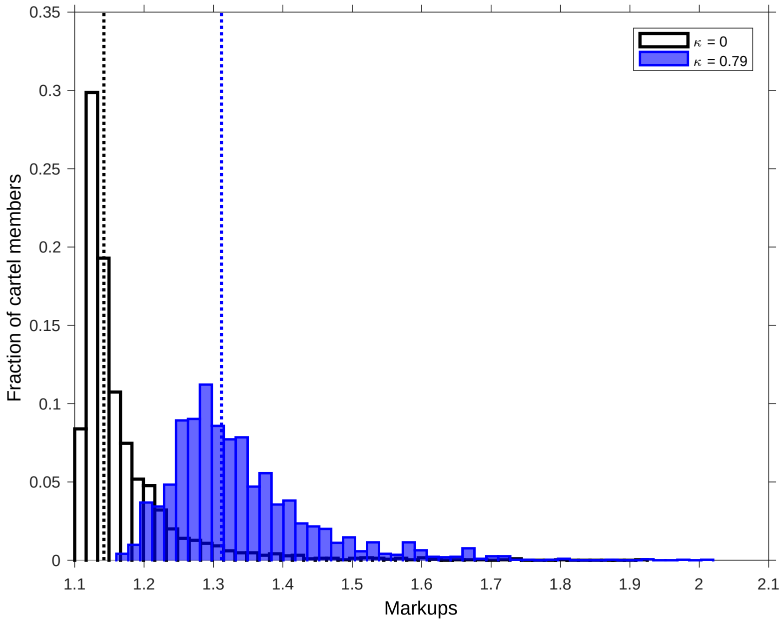
[39] To do so, we have computed the Jacobian matrix of the model's moments with respect to each estimated parameter evaluated at the calibrated value of the parameters (see Figure A6).

[40] This result is consistent with previous findings reported in the case of Taiwan and the US (Edmond et al., 2015, 2022).

Figure 1: Distribution of Cartel Members' Markups



Notes: The figure displays the distribution of cartel members' markups for different values of κ. The median value of each distribution is displayed as a vertical line.

5 How costly are cartels?

We present the aggregate productivity and welfare gains from eliminating the competition distortions that arise because of cartels. We then explore alternative quantitative exercises of interest.

5.1 Aggregate productivity and welfare gains

5.1.1 Productivity

Panel A of Table 6 displays the aggregate productivity gains of breaking down cartels or eliminating markup dispersion altogether starting from a calibrated competitive oligopoly model (column 1) or our calibrated baseline model (columns 2-4).[41] We find that removing all cartels would increase aggregate productivity by 1.1%, as shown in column 2. Indeed, large firms charge lower markups and prices in the competitive equilibrium than in the cartel equilibrium. This contributes to redirecting demand towards top producers, thereby increasing aggregate productivity. Conditional on the composition of cartels, the gains would be higher if the gap between ρ and η was higher. Indeed, the gap between the two elasticities pins down the extent to which dispersion in market shares translates into markup dispersion. Assuming that changes in sectoral concentration have a larger effect on

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[41] Parameter values thus differ across column 1 and columns 2-4.

Table 6: Aggregate Gains from Breaking Down Cartels

Calibrated model:	Competitive	Collusion		
Breaking down:		All cartels	Larger cartels	Smaller cartels
	(1)	(2)	(3)	(4)
Panel A: Aggregate productivity gains, %				
$A_{\text{cartel}} \to A_{\text{comp}}$		1.11	0.88	0.23
$A \to A_{\text{eff}}$	2.16	3.67	3.67	3.67
Distance to efficient allocation		−30.34	−24.08	−6.15
Panel B: Aggregate welfare gains				
$\mathcal{M}_{\text{cartel}} \to \mathcal{M}_{\text{comp}}$ (in pp)		−1.54	−1.16	−0.39
$C_{\text{cartel}} \to C_{\text{comp}}$ (in %)		2.52	1.97	0.54
$K_{\text{cartel}} \to K_{\text{comp}}$ (in %)		4.11	3.16	0.93
$Y_{\text{cartel}} \to Y_{\text{comp}}$ (in %)		2.84	2.20	0.62
$L_{\text{cartel}} \to L_{\text{comp}}$ (in %)		0.53	0.40	0.13
$\mathcal{W}_{\text{cartel}} \to \mathcal{W}_{\text{comp}}$ (in %)		2.00	1.56	0.41
$\mathcal{W} \to \mathcal{W}_{\text{eff}}$ (in %)	4.95	7.83		

Notes: The table displays the aggregate productivity gains (rows 1 to 3) and the change (in points) in the level of the aggregate markup (row 4) resulting from eliminating cartels. The figures are obtained by comparing the variables in the relevant equilibrium to that in the competitive Nash-Cournot equilibrium (row 1) and efficient allocation (row 2). The efficient allocation corresponds to the equilibrium without markup dispersion. The distance to the efficient allocation computed in row 3 is the ratio of the first two rows. Column 1 considers a calibrated competitive oligopoly model whereas columns 2-4 consider our calibrated benchmark model with collusion. Column 3 (4) considers the case where only cartels with a cumulated market share higher (lower) than the median cumulated market share of all cartels are eliminated. The variables in Panel B refer to the aggregate markup, consumption, capital, output, labor and welfare.

sectoral markups than in the French data would generate more markup dispersion and yield a larger cost of cartels. For this reason, we view our static estimate as conservative.

The second row of the table computes the percentage difference between each allocation and its efficient counterpart —see eq. (22). The misallocation cost of markups is 3.7% in the model with collusion. This is higher than what is reported in column 1 because our calibrated oligopoly model with collusion features *more* misallocation than its calibrated competitive counterpart. This shows that competitive oligopoly models, such as Atkeson and Burstein (2008) and more recently Edmond et al. (2015, 2022), may substantially understate the misallocation cost of size-related markups when cartels are made up of top producers as is the case in our context. In fact, the productivity cost of markups computed with respect to the efficient frontier is roughly 70% higher —from 2.16% in the calibrated competitive economy to 3.67% in our calibrated baseline model —in the presence of cartels. The third row shows that removing all cartels would bring the economy 30% closer to the efficient allocation.

Finally, we explore whether the gain from breaking down cartels differs across cartel types. We compute the gain from breaking down large and small cartels, whereby large (small) cartels are defined as cartels with a cumulated market share higher (lower) than the median cumulated market share of all cartels. Dismantling both types of cartels yields different results because larger cartels charge higher markups, so that dismantling them would reallocate relatively more resources towards more productive firms. Columns 3 and 4 show that larger cartels account for about 80% of the gains from breaking down all cartels.

5.1.2 Welfare

The first row of Panel B of Table 6 investigates how removing cartels impacts the level of the aggregate markup.[42] Eliminating all cartels would decrease the aggregate markup by about 1.5 points (column 2). When cartels are broken down, all firms in the cartelized industries start charging lower markups —see Proposition 1. Since larger former cartel members decrease their markup by a larger amount and have a larger market share, this has a large impact on sectoral indices and therefore on the aggregate markup.[43] Finally, the aggregate markup decrease has implications in terms of production, consumption, capital accumulation, labor and welfare. The penultimate row of column 2 shows that breaking down all cartels would lead to a consumption-equivalent welfare gain of 2%.

Interestingly, the last row shows that eliminating markup dispersion altogether and decreasing the aggregate markup to its level in the efficient allocation would increase welfare by 5% and 7.8% starting from the competitive and collusion models, respectively. The fact that these numbers are lower than those reported in the oligopoly version of Edmond et al. (2022) is explained by the fact that both calibrated models initially feature *less* markup dispersion.[44] Nonetheless, columns 1 and 2 show that the welfare gains from reaching the efficient allocation may be largely underestimated if collusion is not appropriately accounted for and cartels are made up of top producers. Another important reference is the recent literature on the dynamic gains from higher markups, where higher markups can raise welfare through increased innovation (Cavenaile et al., 2019). Cartel breakdowns do not generate less innovation through lower profit opportunities in our model. While such dynamic considerations could dominate and overshadow the static gain, this is not a foregone conclusion, even qualitatively. Indeed, the response of innovation to changes in competition is ambiguous, with a hump-shaped relationship between innovation and competition (Aghion et al., 2005). While this remains an open question in our context, the perspective of cartel breakdowns discouraging innovation would suggest that our estimates should be viewed as an upper bound.

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[42] The aggregate markup is computed using the fact that $\mathcal{M} = P \times A$.

[43] Given that the aggregate labor share in the model is the inverse of the aggregate markup level, changes in the degree of cartelization of the economy further generate changes in the labor share due to changes in market concentration (Autor et al., 2020; De Loecker et al., 2020).

[44] Our target of $\hat{\beta} = -0.44$ limits the amount of markup dispersion and thus the gains from reaching the efficient allocation, as already explained. Using similar parameter values as those reported in their paper yields estimates close to theirs —and still lower for the calibrated competitive economy.

Table 7: Differences with Harberger (1954)

	Benchmark (1)	Sectoral level (2)	Unit elastic demand (3)
$A_{\text{cartel}} \rightarrow A_{\text{comp}}$ (in %)	1.11	0.08	0.24

Notes: The table displays the aggregate productivity gains from going to the cartel equilibrium to the the competitive Nash-Cournot equilibrium. Column 1 displays our benchmark results. Column 2 aggregates the model at the sectoral level while unit demand elasticities are used in column 3.

Finally, breaking down large cartels (column 3, Panel B) would lead to a 1.16 percentage point decrease in the aggregate markup, whereas eliminating smaller cartels would decrease it by 0.4 percentage points. This would translate into a 1.6% and 0.4% increase in welfare for large and small cartel breakdowns, respectively. This shows that active competition policies targeting very large cartels can yield sizable gains to aggregate welfare.

5.2 Comparison with Harberger (1954)

Table 7 shows why our results differ from the classic estimate of Harberger (1954) who finds a dead-weight loss arising from monopoly distortions of 0.1% of GDP. Column 2 considers a version of the model in which industries contain a single firm charging a markup equal to the harmonic average of all the other firms' markups. This sectoral version of the model yields an estimate closer to that of Harberger (1954). We find that the aggregate productivity gains from eliminating cartels would be 0.08% without properly accounting for firm heterogeneity within sectors. Finally, to ease the comparison with Harberger (1954), we assume that the demand elasticities in the model are equal to unity.[45] The estimate displayed in column 3 shows that the aggregate productivity gain from breaking down cartels drops to 0.24%. This is because there are very little markup differences across firms when the elasticities of substitution are small, even in the presence of cartels. Eliminating them thus have a very small quantitative effect.

Our results thus point to the importance of properly accounting for heterogeneity within sectors and using appropriate demand elasticities, as also shown recently by Baqaee and Farhi (2020). While our framework abstracts from input-output linkages, it explicitly generates endogenous markups by modelling oligopolistic competition. Our results thus complement theirs by showing that the gains from elimi-

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[45] The result displayed in the table relies on a version of the model in which aggregate consumption c is a Cobb-Douglas aggregator. In the absence of cartels, the price of a firm k is now given by $P_{sk} = \frac{\rho}{(\rho-1)-(\rho-1)\omega_{sk}} \times \frac{W}{z_{sk}}$. We then assume that ρ tends to unity. As an alternative, we also considered a version of our baseline model in which both η and ρ tend towards unity and $\rho > \eta$. We find that the gain from eliminating cartels in this case is equal to 0.18%.

nating total markups in their context or size-related supermarkups in ours are one order of magnitude higher than the estimate of Harberger (1954).

5.3 Aggregate costs of umbrella pricing

Following Proposition 1, *all* firms in a cartelized industry experience a decrease in their prices following the cartel breakdown. Some demand could thus be reallocated towards less productive non-cartel members, thereby dampening the effect of cartel breakdowns on aggregate productivity.

Table A7 examines the quantitative importance of this umbrella pricing effect. Specifically, the markups of non-cartel members are now considered to be exogenous primitives being held fixed in both the cartelized and competitive economy. The markups of cartel members, however, are allowed to decrease to their value obtained in the competitive equilibrium. Column 2 shows that not accounting for the endogenous response of non-cartel members to the increase in competition generated by cartel breakdowns yields slightly higher aggregate productivity gains compared to the benchmark results reported in column 1. The effect on aggregate markups, however, is smaller in absolute value because non-cartel members charge higher prices than they would if they were able to react to the change in competition. The level of the aggregate markup is still important and leads to welfare gains close to what we found previously (2.01% versus 2%).

In short, the endogenous response of non-cartel members attenuates the impact of cartel breakdowns on aggregate productivity and welfare but the effect is quantitatively small.

5.4 Gains from curbing the collusion intensity

In our main quantitative exercise, we have computed the aggregate productivity and welfare gains from *eliminating* cartels. In practice, this goal might be out of reach for antitrust authorities. We now show that antitrust enforcement can nevertheless achieve sizable gains by reducing the collusion *intensity* in the economy, instead of breaking down all cartels. When κ decreases but remains strictly positive, cartels are not dismantled but cartel members assign a lower weight to each other's profits. We thus think of a decrease in κ as a tougher antitrust environment making it harder for cartel members to sustain high markups.[46]

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[46] Firms might be more reluctant to charge higher markups and prices if antitrust authorities can rely on antitrust tools to investigate anticompetitive practices. Specifically, the development of whistle-blower tools or even the threat of increasing fines if customers complain or competition authorities start investigating might deter firms from maintaining the status quo in terms of anti-competitive pricing.

Table 8: Aggregate Gains from Decreasing Collusion Intensity

	$\kappa \to 0.1$ (1)	$\kappa \to 0.2$ (2)	$\kappa \to 0.3$ (3)	$\kappa \to 0.4$ (4)
Panel A: Aggregate productivity gains, in %				
$\mathcal{A}_{\text{cartel}} \to \mathcal{A}_{\text{comp}}$	0.99	0.85	0.70	0.54
$\mathcal{A}_{\text{cartel}} \to \mathcal{A}_{\text{eff}}$	3.67	3.67	3.67	3.67
Distance to efficient allocation	−27.10	−23.22	−19.06	−14.83
Panel B: Aggregate welfare gains				
$\mathcal{M}_{\text{cartel}} \to \mathcal{M}_{\text{comp}}$ (in pp)	−1.06	−0.71	−0.46	−0.28
$C_{\text{cartel}} \to C_{\text{comp}}$ (in %)	2.07	1.67	1.3	0.96
$K_{\text{cartel}} \to K_{\text{comp}}$ (in %)	3.16	2.39	1.75	1.23
$Y_{\text{cartel}} \to Y_{\text{comp}}$ (in %)	2.29	1.81	1.39	1.01
$L_{\text{cartel}} \to L_{\text{comp}}$ (in %)	0.36	0.24	0.15	0.09
$\mathcal{W}_{\text{cartel}} \to \mathcal{W}_{\text{comp}}$ (in %)	1.70	1.41	1.12	0.85

Notes: The table displays the aggregate productivity gains (rows 1 to 3) and the change (in points) in the level of the aggregate markup (row 4) resulting from decreasing the collusion intensity parameter κ from its baseline value of $\kappa = 0.79$. The figures are obtained by comparing the relevant variables in the cartel equilibrium to that in the competitive Nash-Cournot equilibrium (row 1) and efficient allocation (row 2). The efficient allocation corresponds to the equilibrium without markup dispersion. The distance to the efficient allocation computed in row 3 is the ratio of the first two rows. The variables in Panel B refer to the aggregate markup, consumption, capital, output, labor and welfare.

Column 1 of Table 8 considers going from our benchmark value of $\kappa = 0.79$ to $\kappa = 0.1$, while columns 2-4 consider slightly higher weights equal to 0.2, 0.3, and 0.4, respectively. The aggregate productivity gains remain significant, ranging from 0.5% to 1%, and are decreasing in κ. The distance to the efficient allocation and the aggregate markup still decrease when cartel members assign a lower weight to each other but the effect is smaller in absolute value. The welfare gains range from 0.85% to 1.7%.

Our results point to the quantitative importance of the intensive margin of cartels. In this sense, a tougher antitrust environment that forces cartel members to decrease their supracompetitive markups yields substantial aggregate gains.

6 Discussion and robustness

6.1 Discussion

In this section, we examine how our model may be used to test for the presence of cartels through an intuitive screen procedure, before discussing cartel stability.

6.1.1 Cartel screen

Our model yields the following equilibrium equation for inverse markups:

$$\frac{1}{\mu_{sk}^{\mathcal{C}}} = \frac{\rho - 1}{\rho} - \left(\frac{1}{\eta} - \frac{1}{\rho}\right)(1-\kappa)\omega_{sk} - \left(\frac{1}{\eta} - \frac{1}{\rho}\right)\kappa \sum_{j \in \mathcal{C}} \omega_{sj} \tag{24}$$

This equation can be used as a screen to detect collusive behaviors and to recover the value of κ.[47] Under the simple assumption that the production function is log-linear in labor, a firm's inverse markup can be measured by its labor share, yielding the following regression:[48]

$$\frac{Wl_{sk}}{p_{sk}y_{sk}} = a_0 + a_1\omega_{sk} + a_2 \sum_{j \in \mathcal{C}} \omega_{sj} + \epsilon_{sk} \tag{25}$$

where $a_0 = \frac{\rho-1}{\rho}$, $a_1 := \frac{(1-\kappa)(\eta-\rho)}{\eta\rho}$ and $a_2 := \frac{\kappa(\eta-\rho)}{\eta\rho}$. The parameter κ can be recovered from the estimated parameters:

$$\hat{\kappa} = \frac{\hat{a}_2}{\hat{a}_1 + \hat{a}_2} \tag{26}$$

The results are provided in Table A8. The first column reports the regression on the sample of colluding firms without controlling for their joint market share. Firms with a higher market share charge higher markups: the point estimate on a firm's own market share is equal to -0.53 while the intercept is given by 0.70.[49] Both estimates are significant at the 1% level. In column 2, we further include the market share of the whole cartel, which includes each firm's own market share as required by the model. The coefficient on a firm's own market share remains negative but is no longer significant. The joint market share coefficient, however, is negative and significant at the 1% level, which is consistent with the theoretical model. The intercept remains positive and significant. We find that these point estimates yield $\kappa = 0.7$, which is relatively close to our benchmark value of 0.79.[50,51] In column 3,

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[47] Our micro-foundation thus naturally nests the equation used by Brooks et al. (2021) to estimate the extent of cooperative pricing in Chinese special economic zones.

[48] We do not estimate output elasticities to recover firms' markups as we lack data on firm-level prices (Bond et al., 2021).

[49] These values are very close to the ones reported in Edmond et al. (2015) for their sample of Taiwanese firms. They report an intercept for the whole sample of $\hat{a}_0 = 0.64$ and a slope of $\hat{a}_1 = -0.50$.

[50] This estimate is larger than the one found by Brooks et al. (2021). However, our sample differs in that it is based on firms that actually colluded —as they were detected by the antitrust authority. This could explain the higher value of κ that we find compared to their benchmark value of $\kappa = 0.3$.

[51] We note that the parameters ρ, η and κ could, in principle, be inferred from eq. (25). There are at least four reasons to instead rely on our calibration strategy. First, we can directly target a given cartel overcharge to be consistent with competition authorities' assumptions and the literature.

we further include year fixed effects to control for time-varying unobserved heterogeneity common across cartel members. The point estimates and standard errors change very little. The results are qualitatively robust to focusing on price-fixing cartels only (columns 4-6) although the estimated κ is now above one.

Overall, our model can be used to detect collusive behaviors through an intuitive screening equation.

6.1.2 Cartel formation and stability

In this section, we analyze profit incentives of firms and relate them to findings from the theoretical literature on cartel formation (Bos and Harrington, 2010). Our quantitative exercise uses moments from the empirical distribution of detected cartels but has remained agnostic about how cartels form, whether it is rational for a firm to join them, and how collusive arrangements can be sustained over time.

First, consider whether collusion improves the profits of the cartel as a whole in our simulations. This is likely a necessary condition for the cartel to keep operating, although not sufficient. We find that for sufficiently low levels of collusion, almost all cartels are profitable (Figure 2a). In contrast, for high levels of collusion, the aggregate profits of cartel members is lower than in the baseline. Second, we find that there is substantial heterogeneity across cartels, with a right tail of cartel arrangements that would generate aggregate gains for cartel members even at higher levels of collusion (Figure 2b).

The incentives to join a cartel can be derived analytically. Absent side-payments, non-monetary incentives, or threats, the participation constraint for a firm takes the form of an upper-bound on the overcharge Θ_{sk} it sets when joining the cartel —see Appendix B.5:

$$\Theta_{sk} < \left[\frac{\rho - \eta}{\rho - \varepsilon_{sk}} - \Upsilon_{sk} \right] \hat{P}_s^C \tag{27}$$

Note that the term in brackets is decreasing with size, that is, the constraint is less binding for smaller firms. The intuition is that, compared to the initial situation, smaller firms who are mostly price takers stand to gain from the increase in prices triggered by the cartel. However, firms also have an incentive to free-ride on the cartel, that is, benefit from the sectoral price level increase while not charging a collusive overcharge. For a cartel to be sustainable, there must exist a discount

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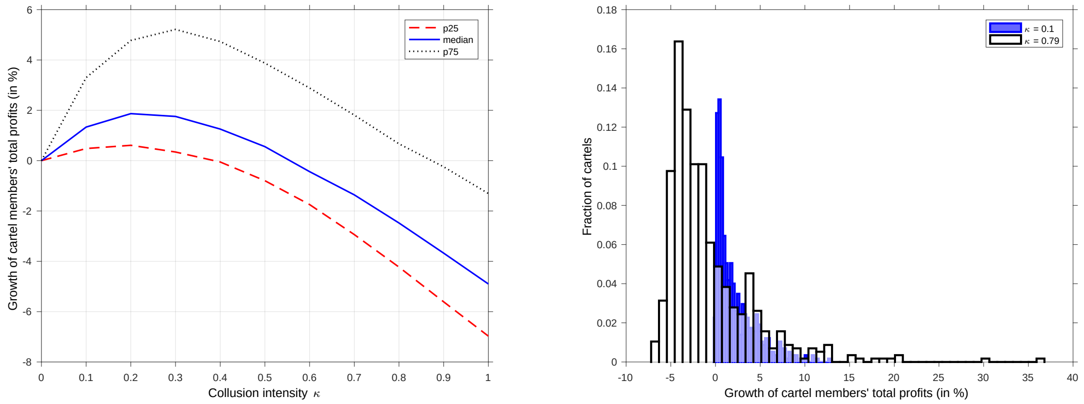
Second, this helps us build the bridge with previous work targeting similar moments (Atkeson and Burstein, 2008; Edmond et al., 2022; Burstein et al., 2020). Third, taken at face value, the constant term in Table A8 would yield a negative ρ parameter, which is inconsistent with the theoretical restriction that $1 < \eta < \rho$. The observation that it might be hard to find parameter values consistent with this restriction and that can rationalize observed markup dispersion is further developed in Blaum et al. (2018). Finally, one can allow κ to vary across cartels by specifying a probability distribution, an issue we turn to in the next section.

Figure 2: Profits of Cartels in the Collusive and Competitive Equilibrium



(a) Distribution (b) Given κ

Notes: Panel a) displays the p25, median and p75 of the distribution of the growth rate of cartel member's total profits for different values of κ. The growth rate is computed as the difference in total profits for each cartel in each sector before and after colluding. Panel b) displays the distribution of the growth rate of cartels' total profits for different values of κ. The growth rate is computed as the difference in total profits for each symmetric cartel in each sector before and after colluding. As the collusion intensity increases, the distribution of aggregate gains shifts to the left.

factor δ such that each firm satisfies the following incentive compatibility constraint:

$$\Theta_{sk} < \left[\frac{\rho-\eta}{\rho-\varepsilon_{sk}} - \Upsilon_{sk}\right]\left[\hat{P}_s^{\mathcal{C}} - (1-\delta)\,\hat{P}_{sk}^{\mathcal{C}\setminus\{k\}}\right] \tag{28}$$

where $\hat{P}_{sk}^{\mathcal{C}\setminus\{k\}}$ is the price level increase if all the other cartel members except for firm k apply the overcharge. Notice that this constraint is always tighter than the participation constraint in eq. (27),[52] and is no longer monotonically decreasing as the term in the rightmost brackets increases with size. This reflects the fact that, since larger firms have a larger price impact, the price level increase triggered by the cartel would be relatively much smaller if they opt to free-ride. Conversely, for small firms with little market impact, profit incentives can be insufficient in themselves to induce them to join the cartel, which would be consistent with the use of threats or non-monetary incentives.

Endogenizing the cartel formation choice of firms into our model would allow studying in greater depth the aggregate cost of potentially different cartel composition cases across industries. This is an important direction for future research.

6.2 Robustness

In this section, we test the sensitivity of our results to alternative target values, modes of competition, and settings with heterogenous κ across cartels. The results

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[52] In fact, when firms are infinitely patient ($\delta = 1$), it reduces exactly to the participation constraint.

Table 9: Aggregate Gains from Breaking Down Cartels: Robustness Experiments

	Overcharge 15% (1)	$\mathcal{M} = 1.1$ (2)	$\mathcal{M} = 1.3$ (3)	Bertrand (4)
$\mathcal{A}_{\text{cartel}} \rightarrow \mathcal{A}_{\text{comp}}$	1.63	1.37	0.90	0.55
$\mathcal{A}_{\text{cartel}} \rightarrow \mathcal{A}_{\text{eff}}$	4.19	3.71	3.74	1.40
Distance to efficient allocation	−38.85	−36.91	−23.98	−39.17
$\mathcal{M}_{\text{cartel}} \rightarrow \mathcal{M}_{\text{comp}}$ (in pp)	−1.50	−0.43	−2.34	−2.25
$C_{\text{cartel}} \rightarrow C_{\text{comp}}$ (in %)	3.31	2.30	2.61	2.07
$K_{\text{cartel}} \rightarrow K_{\text{comp}}$ (in %)	4.90	2.79	4.88	4.38
$Y_{\text{cartel}} \rightarrow Y_{\text{comp}}$ (in %)	3.62	2.41	3.03	2.53
$L_{\text{cartel}} \rightarrow L_{\text{comp}}$ (in %)	0.53	0.16	0.76	0.77
$\mathcal{W}_{\text{cartel}} \rightarrow \mathcal{W}_{\text{comp}}$ (in %)	2.77	2.07	1.96	1.35

	Het. κ $\sigma^2_{\mathcal{N}} = 0.5$ (5)	Het. κ $\sigma^2_{\mathcal{N}} = 1$ (6)	Het. κ $\sigma^2_{\mathcal{N}} = 2$ (7)	Het. κ $\sigma^2_{\mathcal{N}} = 4$ (8)
$\mathcal{A}_{\text{cartel}} \rightarrow \mathcal{A}_{\text{comp}}$	1.10	1.11	0.95	0.84
$\mathcal{A}_{\text{cartel}} \rightarrow \mathcal{A}_{\text{eff}}$	3.66	3.67	3.71	3.52
Distance to efficient allocation	−30.17	−30.28	−25.60	−23.78
$\mathcal{M}_{\text{cartel}} \rightarrow \mathcal{M}_{\text{comp}}$ (in pp)	−1.40	−1.53	−1.33	−1.26
$C_{\text{cartel}} \rightarrow C_{\text{comp}}$ (in %)	2.45	2.50	2.16	1.98
$K_{\text{cartel}} \rightarrow K_{\text{comp}}$ (in %)	3.92	4.05	3.54	3.35
$Y_{\text{cartel}} \rightarrow Y_{\text{comp}}$ (in %)	2.74	2.81	2.43	2.25
$L_{\text{cartel}} \rightarrow L_{\text{comp}}$ (in %)	0.49	0.52	0.46	0.46
$\mathcal{W}_{\text{cartel}} \rightarrow \mathcal{W}_{\text{comp}}$ (in %)	1.96	1.99	1.71	1.53
P25 κ	0.78	0.61	0.36	0.29
Median κ	0.89	0.80	0.62	0.55
P75 κ	0.95	0.91	0.82	0.78

Notes: The table displays the aggregate productivity gains (rows 1 to 3) and the change (in points) in aggregate markups resulting from eliminating cartels (row 4). The figures are obtained by comparing the relevant variables in the cartel equilibrium to that in the competitive Nash-Cournot equilibrium (row 1) and efficient allocation (row 2). The efficient allocation corresponds to the equilibrium without markup dispersion. The distance to the efficient allocation computed in row 3 is the ratio of the first two rows. The low (high) markup target in column 1 (2) of Panel A is set to 1.1 (1.3). The target for the median number of cartel members is set to four in column 3 of Panel A. In column 4 of Panel A, firms compete in prices (see Appendix). The low (high) ρ value in column 1 (2) of Panel B is set to 5 (20). The low (high) κ value in column 3 (4) of Panel B is set to 0.3 (1).

are displayed in Table 9. We recalibrate the model for each robustness experiment to match the relevant targets.

Alternative cartel overcharge target. Our estimated gains rely on a value of κ chosen so as to match a median cartel overcharge of 10%. Given the importance of this parameter for the quantification of the gains from breaking down cartels, we recalibrate the model so as to match a median cartel overcharge of 15% (column 1).

Not surprisingly, the intensity of collusion required to match this alternative moment is higher, $\kappa = 1.28$. In this exercise, aggregate productivity and consumption-equivalent welfare would increase by 1.6% and 2.8%, respectively, if firms were to behave competitively. In short, our benchmark estimates are conservative to the extent that requiring the model to match a higher overcharge target yields larger gains from dismantling cartels.

Alternative aggregate markup targets. Another important moment is the aggregate markup level, which is set equal to 1.2 for our benchmark results. Given the paucity of estimates for France, we consider two alternative values for this calibration target. The low (high) markup target is set equal to 1.1 (1.3). As shown in columns 2 and 3 of Table 9, the productivity gains from breaking down cartels remain important, ranging from 0.9% to 1.4%. The consumption-equivalent welfare gains range from 2% to 2.1%. Targeting alternative aggregate markup values does not yield dramatic differences with our benchmark estimates. Why is this the case? While ρ and η adjust to match this target —for instance, $\rho = 22.3$ and $\eta = 2.01$ to match $\mathcal{M} = 1.1$, the relative gap between the two parameters is still governed by the moment $\hat{\beta} = -0.44$. As a result of this, the amount of markup dispersion generated in the cartel allocation, and thus the gains from breaking down cartels, do not change dramatically either.

Bertrand competition. In our benchmark model, firms compete à la Cournot. We relax this assumption and instead assume that firms compete in prices in column 4.[53] As shown in Appendix B.6, the only point of departure from our benchmark model is that the demand elasticity is now a weighted arithmetic average of ρ and η. We find that the aggregate productivity gain is equal to 0.55% and is thus smaller than when firms compete in quantities. This is because the Bertrand model features considerably less markup dispersion. This can also be seen from the fact that the cartelized economy is closer to the efficient allocation than before (row 2). Eliminating cartels reduces the distance to the efficient frontier by about 39%, however. The model nevertheless generates a larger change in the *level* of the aggregate markup which decreases by 2.25 percentage points. This translates into a consumption-equivalent welfare gain of 1.35%.

Heterogeneous κ. We now allow κ to vary across cartels, i.e., we generate a distribution of intensity of collusion parameters κ_C. Specifically, we model each cartel's

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[53] Given that the Bertrand competition model does not generate eq. (23), we instead set a parameter value for η close to its benchmark value, $\eta = 2$. The other parameters are chosen so as to match all the other moments. We have also experienced with setting $\eta = 1.01$: the results remain qualitatively and quantitatively similar.

intensity of collusion as a random draw from a truncated Normal distribution over the unit interval with mean $\mu_{\mathcal{N}}$ and variance $\sigma^2_{\mathcal{N}}$. The mean parameter $\mu_{\mathcal{N}}$ is chosen such that the model-generated median cartel overcharge matches its target of 10%. We experiment with four different values of the variance parameter $\sigma^2_{\mathcal{N}}$.

Allowing κ to vary across cartels yields aggregate productivity gains from eliminating cartels ranging from 0.84% to 1.11%, close to our benchmark estimate of 1.11%, whereas the welfare gains range from 1.53% to 1.99%, in line with our benchmark estimate of 2%. Depending on the variance parameter chosen, the median value of κ ranges from 0.55 to 0.89. As the variance increases, the median value of κ decreases and so does the median cartel overcharge. For instance, in column 8, the model generates a median cartel overcharge of 6.4% instead of our target of 10%. Interestingly, allowing κ to vary across sectors and setting the variance parameter equal to 0.5 or 1 yields results remarkably close to our benchmark estimates. Overall, this additional set of results provides reassuring evidence that assuming a homogeneous collusion intensity parameter does not significantly affect our quantitative results.

7 Conclusion

We study the impact of collusion on aggregate productivity and welfare. We build an oligopolistic competition model with heterogeneous firms and show how collusion can amplify or dampen misallocation in otherwise standard competitive oligopoly models. In addition, we show that our framework generates a microfounded screen allowing to detect horizontal cartels and that mild forms of collusion can be consistent with firms' rational behavior.

Calibrating our model to French data, we find that there are important economic gains from breaking down cartels. Specifically, eliminating cartels would raise aggregate TFP by 1.1% and welfare by 2% in consumption-equivalent terms. In terms of policy, our results suggest that antitrust enforcement and competition laws that aim to break down cartels can yield large gains. Moreover, to ensure that cartels do not form and dampen productivity gains, other policies aiming to promote economic growth such as industrial policies or trade liberalization reforms may also be accompanied by robust competition laws. Although our estimates are sizable, they should be interpreted with care. Indeed, our numbers reflect the static cost of cartels. Cartels may impose or reinforce barriers to entry, thereby preventing productive firms from entering an industry, or allowing low-productivity firms to enter industries with low barriers to entry (Carrera and Titov, 2019). They may also increase innovation by boosting profits in the longer run.

There are several directions our work could take. First, collusion and misallocation are likely important issues in several emerging markets and developing economies —see Reed et al. (2022) for the case of Mexico. Second, our framework could be used to study the impact of horizontal M&As on aggregate productivity, by allowing for eventual cost synergies. Third, we focused on product-side distortions created by cartels, while several recent important court cases involve conspiracies involving firms agreeing not to compete on the labor market. Finally, incorporating input-output linkages would be an important undertaking to understand how cartelization may affect firms along the supply chain. These important questions are left for future research.

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Online Appendix

"How Costly Are Cartels?"

Flavien Moreau and Ludovic Panon

A Data Appendix

A.1 Institutional Background

Despite a strong tradition in industrial policy, antitrust regulation in France has a relatively short formal history. It can be roughly simplified into four periods, during which the competition regulator changed its name several times, and saw its mission successively specified and broadened. First established in 1953,[54] the French Technical Commission for Collusions and Dominant Positions' main goal was the fight against cartels and widespread price fixing in post-war France. In 1963, the Commission's objectives were extended to allow the formal investigation of cases of dominant positions.[55] In practice, this Commission would directly notify the Economic Ministry, which would then decide whether to impose fines.

Following the 1973 oil crisis, Prime Minister Raymond Barre and also an economics professor, advocated a stronger control of price fixing arising from anti-competitive behaviors. In 1977, the Commission became the Competition Commission (*Commission de la Concurrence*). In parallel of its mandate of detecting cartel and abuse of dominant positions, the Commission was to advise the French government on all competition-related matters, including on vertical and horizontal mergers and acquisitions.

The period 1986 to 2009 is important as it spans the beginning of our empirical analysis. Over this period, the Commission undergoes important transformations: its name is changed to the Competition Council (*Conseil de la Concurrence*) and the 1986 Ordinance introduces several changes. Companies can directly refer cases to the Council. Moreover, the antitrust body becomes more independent, better protects concerned parties' rights and is now able to directly fine the firms found guilty of anti-competitive practices, though this does not apply to merger projects. The 2001 New Economic Regulation Law further introduces leniency and transaction programs to better detect and fight cartels.[56]

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[54] Décret n°53-704 du 9 août 1953.

[55] Loi n°63-628 du 2 juillet 1963.

[56] A firm part of a cartel can go to the authority and report it. Under specific circumstances the firm will receive a more lenient fine that the other members of the cartels or not be fined at all. Large cartels dismantled through a leniency program can be found here.

Finally, as of 2008, the Competition Council turns into the Competition Authority (*Autorité de la Concurrence* or ADLC, henceforth). The 2008 Law on the Modernization of Economy not only gives the right to the Authority to review merger and acquisitions independently from the Minister of Economy, but also to investigate potential anti-competitive cases on its own.

There are two tools in ADLC's arsenal: fines and injunctions. Fines are set "according to the seriousness of the facts, the extent of the harm done to the economy, the individual situation of the company that has committed the infringement and of the group to which it belongs to, and whether it is an infringement that has been repeated or not".[57] Fines are capped at "10% of the global turnover of the group to which the company that is being fined belongs to" or at a maximum amount of the fine capped at 3 million euros if the infringement is committed by an entity other than a for-profit firm.[58] Alternatively the ADLC can issue injunctions to formally notify companies to stop anticompetitive behavior.

A.2 Firm-level Database on Cartels

In order to extract information on the identity of the firms fined by the ADLC we proceed as follows. First, we scrape the website of the ADLC to recover all the decision files over the period 1994-2019. These PDF documents contain information on the situation of the market impacted by anti-competitive behaviors, the notification date of the case to the ADLC, the names of the firms fined for anti-competitive behaviors, the types of infraction they committed, their sales and the duration of the infraction. Some of these files contain information on when the firms were notified by the ADLC that an investigation is going to be launched. Extracting and getting data on the identity of these anti-competitive companies is straightforward to the extent that the layout is relatively similar across decision files. A salient and important example is that of the companies' name which always appears at the end of the PDF right after the word *Décide* ("Decides").

Second, we use Python's textual analysis tools to back out the name of these companies, their sales, the date when the ADLC was first notified of the infraction and the corresponding amount of the fine for each firm. This step requires some manual cleaning as some companies, numbers and cases are misreported. We therefore go through all the files to complement the information extracted from the textual analysis and double check that our newly created dataset is not missing anything that would appear in the original PDF files but that we would miss via the textual analysis exercise. At this stage, the dataset is informative about the

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[57] French Commercial Code, L.420-1 or L.420-2.

[58] French Commercial Code, L.464-2.

identity (name) of the firms that were fined by the French Antitrust Authority, their sales, the case number of the decision, the amount of the fine for each firm and the notification date of the case to the ADLC.

Third, we make use of Orbis and Python to recover information on the identification number of the firms which will then allow us to match our database to the balance-sheet data. To do so, we upload our temporary database into the Batch Search engine of Orbis to look for the SIREN number of each firm given its name. We complement this information with a Python script that allows us to obtain the SIREN number of firms based on a Bing search of that firm's name.[59] Although these methods are imperfect, they facilitate the matching with FICUS.

Finally, before matching our database with FICUS, we manually verify that the SIREN numbers obtained from Orbis and from our scraping procedure are correct. We do so by making sure that the sales (in euros) of the firm in our database correspond to those reported in FICUS. For the firms that were not matched by any means in our third step, we manually search for them in FICUS using the information on their sales and add their SIREN number directly in our database.

A.3 List of Variables

We describe below the different variables used in our empirical framework. Note that our main sample consists of observations with strictly positive values for gross value-added, total and domestic sales, number of employees, labor compensation, expenditures on materials and capital.

- **APE Code:** 4-digit industry code. Before 2008, APE codes are available in a 4-digit format corresponding to the NAF Rev. 1 classification. *Source: FICUS and authors' calculation*

- **Capital:** Net book value of capital. We cannot build a capital measure using the perpetual inventory method. We further deflate capital expenditures by sector-level price indices from EUKLEMS (Jäger, 2017). *Source: FICUS and authors' calculation*

- **Colluder:** Dummy variable that takes the value one if the firm engaged in anti-competitive practices in a given year. *Source: Moreau-Panon database*

- **Employment:** Total number of employees working in each firm. *Source: FICUS*

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[59] We thank Arthur Guillouzouic Le Corff for sharing his code.

- **Gross Value-Added:** This variable is directly available in FICUS and follows the accounting definition according to which it is equal to total sales minus input expenses taking into account changes in inventories. *Source: FICUS*
- **Labor Compensation:** This variable is the sum of two components separately available in the fiscal files: salaries and social benefits that are paid by the employer and that benefit the worker in the form of retirement funds, social security funds etc. *Source: FICUS*
- **Market Shares:** A firm's market share is defined at the 4-digit level. We compute market shares by dividing a firm's domestic sales by the total amount sold by all the firms operating in the same market at a point in time. *Source: FICUS and authors' calculation*
- **Materials:** Materials are defined as the sum of expenditures on raw materials, final goods and other categories. We further deflate this expenditure variable by 2-digit sector intermediate goods price indices from EUKLEMS. *Source: FICUS and authors' calculation*
- **NAF Code:** 2-digit sector code according to the NACE Rev. 1 classification. Some sectors are pooled together, depending to the availability of sector-price deflators. *Source: FICUS*
- **Total Sales:** Total sales (domestic sales plus export sales) reported by the firm in thousands of euros. *Source: FICUS*
- **Wages:** Firm-level wages are obtained by dividing labor compensation by employment. *Source: FICUS and authors' calculation*

Market definition. We use both 2-digit and 4-digit industry classification. In the FICUS dataset, each firm is assigned a 4-digit principal activity code ("Code APE") by the INSEE and whose aim is to pin down in which industry the firm mostly operates. Because the precise breakdown of sales across products is not available for the French data, the relevant market of a firm is its 4-digit industry code. Therefore, throughout the paper, we will denote a firm's market share by its market share in the relevant 4-digit industry code. Our definition of a sector follows the NAF Rev. 1 classification.

B Mathematical Appendix

B.1 Cartels and Market Structure

This section derives equilibrium conditions when a subset of firms in each sector s belong to a cartel $\mathcal{C}$: $\mathcal{C}_s \subseteq K_s$ and non-cartel members behave competitively.

Cartels and cross-ownership. The simple form of collusion analyzed in the main text is meant to capture a large range of cartel arrangements, and is also consistent with the profit distortions created by cross-ownership. To see this, consider an industry with K firms, let Π_k denote the profit function of firm k. Let β_{jl} denote the share of firm j which is owned by firm l and γ_{lj} firm l's control or influence over firm j's decisions. The financial profits accruing to firm l correspond to the portfolio $\pi^l = \sum_j \beta_{jl}\pi_j$, where π_l are the profits generated by firm l's operations. However, because other firms can influence firm k's operations, and that their shareholders' interests are not perfectly aligned, the managers of firm k maximize a weighted average, $\tilde{\pi}_k$, of the firm's shareholders portfolios, where the weights depend on the controlling shares. The objective function of firm k is given by:

$$\tilde{\pi}_k = \sum_l \gamma_{kl}\pi^l = \sum_l \gamma_{kl}\sum_j \beta_{jl}\pi_j \tag{29}$$

Taking π_k out of the second summation and normalizing by $\sum_l \gamma_{kl}\beta_{kl}$ so as to isolate π_k, we can rewrite the objective function as (dropping the sectoral index s):

$$\tilde{\pi}_k \propto \pi_k + \sum_{j\in\mathcal{C}\setminus\{k\}} \frac{\sum_l \gamma_{kl}\beta_{jl}}{\sum_l \gamma_{kl}\beta_{kl}}\pi_j = \pi_k + \sum_{j\in\mathcal{C}\setminus\{k\}} \kappa_{kj}\pi_j \tag{30}$$

Equation (30) makes it clear that firm k maximizes its own profits given by π_{sk} *and* other firms' profits. Moreover, the profit weights are *firm*-specific.[60] Cartel members therefore solve the following maximization problem:

$$\max_{P_{sk},q_{sk}} \left[\left(P_{sk} - \frac{W}{z_{sk}}\right)q_{sk} + \sum_{j\in\mathcal{C}\setminus\{k\}} \kappa_{kj}\left(P_{sj} - \frac{W}{z_{sj}}\right)q_{sj}\right], \quad \forall k \in \mathcal{C}_s \tag{31}$$

subject to the inverse demand function obtained by combining eq. (3) and eq. (6):

$$\left(\frac{P_{sk}}{P}\right) = \left(\frac{q_{sk}}{y_s}\right)^{-\frac{1}{\rho}}\left(\frac{y_s}{c}\right)^{-\frac{1}{\eta}} \tag{32}$$

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[60] We note that these profit weights can be larger than one, in which case a firm values other firms' profits more than its own. Such a case is studied in Backus et al. (2019).

and where $\kappa_{kj} := \frac{\sum_l \gamma_{kl}\beta_{jl}}{\sum_l \gamma_{kl}\beta_{kl}}$ is the firm-specific weight assigned to other cartel members' profits.

Non-cartel members. Competitive firms that do not belong to the cartel ($i \notin \mathcal{C}_s$) instead maximize their own profits. Their prices P_{si} and quantities q_{si} solve the following maximization problem:

$$\max_{P_{si},q_{si}} \left[\left(P_{si} - \frac{W}{z_{si}} \right) q_{si} \right], \quad \forall i \notin \mathcal{C}_s \tag{33}$$

subject to eq. (32):

$$\left(\frac{P_{si}}{P} \right) = \left(\frac{q_{si}}{y_s} \right)^{-\frac{1}{\rho}} \left(\frac{y_s}{c} \right)^{-\frac{1}{\eta}} \tag{34}$$

Equilibrium prices and markups. Under Nash-Cournot competition, the equilibrium prices $\tilde{P}_{sk}$ of each cartel member and P_{si} of each non-cartel member are characterized by

$$\begin{aligned} \tilde{P}_{sk} &= \tilde{\mu}_{sk} \frac{W}{z_k}, \quad \forall k \in \mathcal{C} \\ P_{si} &= \mu_{si} \frac{W}{z_i}, \quad \forall i \notin \mathcal{C} \end{aligned} \tag{35}$$

where firm-level markups are given by

$$\begin{aligned} \frac{1}{\tilde{\mu}_{sk}} &= \frac{\rho - 1}{\rho} + \frac{\eta - \rho}{\eta\rho} \left(\omega_{sk} + \sum_{j \in \mathcal{C} \setminus \{k\}} \kappa_{kj} \omega_{sj} \right), \quad \forall k \in \mathcal{C} \\ \frac{1}{\mu_{si}} &= \frac{\rho - 1}{\rho} + \frac{\eta - \rho}{\eta\rho} \omega_{si}, \quad \forall i \notin \mathcal{C} \end{aligned} \tag{36}$$

and where ω_{sk} is the market share of firm k in its sector s:

$$\omega_{sk} := \frac{P_{sk} q_{sk}}{\sum_{j=1}^{K} P_{sj} q_{sj}} = \left(\frac{P_{sk}}{P_s} \right)^{1-\rho} \tag{37}$$

To see this, given the definition of sectoral output y_s in eq. (5) and the inverse demand function of eq. (32), prices P_{sk} can be rewritten as:

$$P_{sk} = P c^{\frac{1}{\eta}} q_{sk}^{-\frac{1}{\rho}} y_s^{\frac{\eta-\rho}{\eta\rho}} = P c^{\frac{1}{\eta}} q_{sk}^{-\frac{1}{\rho}} \left(\sum_{k=1}^{K_s} (q_{sk})^{\frac{\rho-1}{\rho}} \right)^{\frac{\eta-\rho}{\eta(\rho-1)}} \tag{38}$$

Using the previous equation in the maximization problem detailed in eq. (33) yields:

$$\max_{q_{sk}} \left[P c^{\frac{1}{\eta}} q_{sk}^{\frac{\rho-1}{\rho}} \left(\sum_{k=1}^{K_s} (q_{sk})^{\frac{\rho-1}{\rho}} \right)^{\frac{\eta-\rho}{\eta(\rho-1)}} - \frac{W}{z_{sk}} q_{sk} \right], \quad \forall k \notin \mathcal{C}$$

Firms do not internalize the effect of their decision on c and P and take wages and productivity levels as given. The first-order condition with respect to q_{sk} yields:

$$P_{sk} \frac{\rho-1}{\rho} + \frac{q_{sk}^{\frac{\rho-1}{\rho}}}{\sum_{j=1}^{K_s} q_{sj}^{\frac{\rho-1}{\rho}}} \frac{\eta-\rho}{\eta\rho} P_{sk} - \frac{W}{z_{sk}} = 0$$

Given the CES inverse demand functions given in eq. (6), the market share of a firm in its sector ω_{sk} can be expressed as $\omega_{sk} = \frac{q_{sk}^{\frac{\rho-1}{\rho}}}{\sum_{j=1}^{K_s} q_{sj}^{\frac{\rho-1}{\rho}}}$. Using this expression and rearranging the first-order condition yields:

$$P_{sk} = \left[1 - \frac{1}{\rho}(1-\omega_{sk}) - \frac{1}{\eta}\omega_{sk} \right]^{-1} \times \frac{W}{z_{sk}} \tag{39}$$

Defining the demand elasticity as $\varepsilon(\omega_{sk}) = \left[\frac{1}{\rho}(1-\omega_{sk}) + \frac{1}{\eta}\omega_{sk} \right]^{-1}$ and rearranging the previous equation yields eq. (35) for non-cartel members.

Similarly, the problem solved by cartel members in eq. (31) can be written as:

$$\begin{aligned} \max_{q_{sk}} \Bigg[& P c^{\frac{1}{\eta}} q_{sk}^{\frac{\rho-1}{\rho}} \left(\sum_{k=1}^{K_s} (q_{sk})^{\frac{\rho-1}{\rho}} \right)^{\frac{\eta-\rho}{\eta(\rho-1)}} - \frac{W}{z_{sk}} q_{sk} \\ & + \sum_{j \neq k} \kappa_{kj} \left(P c^{\frac{1}{\eta}} q_{sj}^{\frac{\rho-1}{\rho}} \left(\sum_{k=1}^{K_s} (q_{sk})^{\frac{\rho-1}{\rho}} \right)^{\frac{\eta-\rho}{\eta(\rho-1)}} - \frac{W}{z_{sj}} q_{sj} \right) \Bigg] \end{aligned}$$

Taking the derivative of this equation with respect to q_{sk} yields:

$$\frac{\partial \tilde{\pi}_{sk}}{\partial q_{sk}} = \frac{\partial \Pi_{sk}(q_{sk}, q_{s-k})}{\partial q_{sk}} + \sum_{j \neq k} \kappa_{skj} \frac{\partial \Pi_{sj}(q_{sk}, q_{s-k})}{\partial q_{sk}}$$

The first term is exactly the same as in the FOC without collusion while the second term is the additional term created by the cartel, whereby a firm internalizes only partially the positive externality on the other members of the cartel. This can be rewritten as:

$$\frac{\partial \tilde{\pi}_{sk}}{\partial q_{sk}} = \left[1 - \left\{ \frac{1}{\rho} + \left(\frac{1}{\eta} - \frac{1}{\rho} \right) \omega_{sk} \right\} \right] P_{sk} - \frac{W}{z_{sk}} + \sum_{j \neq k} \kappa_{skj} \frac{\partial P_{sj}}{\partial q_{sk}} q_{sj}$$

where

$$\frac{\partial P_{sj}}{\partial q_{sk}} q_{sj} = \left(\frac{1}{\rho} - \frac{1}{\eta} \right) P_{sk} \omega_{sj} \tag{40}$$

Collecting the terms and rearranging yields the equilibrium price of cartel members shown in eq. (35) with the equilibrium markups expressed as in eq. (36). The parameter κ_{kj} controls the degree of symmetry of the cartel agreement. If $\kappa_{kj} = 1$ then a member of the cartel cares equally about her own-profits than that of other members of the cartel. In this extreme case, all the members of the cartels set the same markup, that depends only on the sum of the equilibrium market shares of the cartel members. Conversely, $\kappa_{kj} = 0$ corresponds to the competitive Nash-Cournot equilbrium.

Full symmetric collusion. Consider the case where the profit weights are equal to unity $\kappa_{kj} = 1$. This is the case, for example, when the share of two different rival firms j and k owned by investor l is the same, *i.e.* $\beta_{jl} = \beta_{kl}$. This also arises when the control shares are the same across firms $\gamma_{kl} = \gamma_k$.[61] The case where the profit weights are equal to unity boils down to full collusion where firms maximize their joint profits and equally weight all cartel members' profits. Cartel member k's markup is given by:

$$\frac{1}{\tilde{\mu}_{sk}} = \frac{\rho - 1}{\rho} + \frac{\eta - \rho}{\eta\rho} \sum_{j \in \mathcal{C}} \omega_{sj} \tag{41}$$

All colluding firms that belong to $\mathcal{C}$ charge the same markup that is governed by the combined market share $\sum_{j \in \mathcal{C}} \omega_{sj}$.

Partial symmetric collusion. Consider the case where the profit weights differ from unity but are *constant* across cartel members. This is the case when firms' ownership shares are constant across different firms so that $\beta_{jl} = \beta_j$ and $\beta_{kl} = \beta_k$. These shares can vary so that $\beta_j \neq \beta_k$ as long as certain parametric restrictions are satisfied. For instance, if $\beta_j \propto \kappa^{\zeta_j}$, $\beta_k \propto \kappa^{\zeta_k}$ and $\zeta_j - \zeta_k = 1$, the profit weights are equal to κ. We assume that $\kappa \in (0, 1)$, $\zeta_j > 0$, $\zeta_k > 0$. In this case $\kappa_{kj} = \frac{\sum_l \gamma_{kl} \beta_{jl}}{\sum_l \gamma_{kl} \beta_{kl}} = \frac{\beta_j}{\beta_k} = \frac{\kappa^{\zeta_j}}{\kappa^{\zeta_k}} = \kappa$ where the last step follows from $\zeta_j - \zeta_k = 1$. Markups are given by:

$$\frac{1}{\tilde{\mu}_{sk}} = \frac{\rho - 1}{\rho} + \frac{\eta - \rho}{\eta\rho} \left(\omega_{sk} + \kappa \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj} \right) \tag{42}$$

Equation (42) generates markup dispersion as each cartel member's decision's impact on other cartel members' profits is not fully internalized. As a result, markups depend on both the firm's own market share and the combined market share of the

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[61] The profit weights also equal unity in this case as $\sum_l \beta_{jl} = 1$.

cartel. Markup dispersion across cartel members is higher in this case than in the full collusion case, as the weights assigned to other cartel members are not necessarily equal to one.

B.2 Proof of Proposition 1

Proposition 1. (Reminded) *Starting from the competitive equilibrium, symmetric collusion i) increases the sectoral price index and ii) increases the markups of all firms. In particular, iii) for cartel members, the markup increase declines with firm size iv) while for non-cartel members, the markup increase increases with firm size.*

Proof. We study the economy as it transitions from the competitive Nash-Cournot equilibrium at time t to a small level of collusion $\Delta\kappa$ at time $t+\Delta t$. For any variable x_t, we let x denote the value of the variable in the initial equilibrium and $\hat{x}$ denote the log change between time t and $t+\Delta t$, that is,

$$\hat{x}_{sk} := \log x_{sk,t+\Delta t} - \log x_{sk,t} \tag{43}$$

and we drop the time index henceforth to simplify notations.

For non-cartel members, differentiating the markup equation around the competitive equilibrium, we have

$$\hat{\mu}_{sk} = \mu_{sk}\left(\frac{1}{\eta}-\frac{1}{\rho}\right)\bigg(\omega_{sk}\hat{\omega}_{sk}\bigg) \tag{44}$$

Using eq. (37), the response of market shares to relative price changes, at the first order, is equal to

$$\hat{\omega}_{sk} = (1-\rho)\left(\hat{P}_{sk}-\hat{P}_s\right) \tag{45}$$

Because there are no shocks to fundamental productivity levels, prices only change because of a change in markup, $\hat{P}_{sk}=\hat{\mu}_{sk}$. Combining with eq. (44), we obtain the price response:

$$\hat{P}_{sk} = \mu_{sk}\left(\frac{1}{\eta}-\frac{1}{\rho}\right)\bigg(\omega_{sk}(\rho-1)\left(\hat{P}_s-\hat{P}_{sk}\right)\bigg) \tag{46}$$

Collecting the terms we obtain

$$\hat{P}_{sk} = \Upsilon_{sk}\hat{P}_s \tag{47}$$

where we define

$$\Upsilon_{sk} := \frac{\omega_{sk}(\rho-1)\left(\frac{1}{\eta}-\frac{1}{\rho}\right)\mu_{sk}}{1+\omega_{sk}(\rho-1)\left(\frac{1}{\eta}-\frac{1}{\rho}\right)\mu_{sk}} \tag{48}$$

to denote the umbrella pricing effect. Note that since this effect is of the form $x \to \frac{ax}{1+ax}$ with $a > 0$, this umbrella pricing effect is increasing with firm size. The change in market shares for non-cartel firms can be expressed as:

$$\hat{\omega}_{sk} = (\rho - 1)\left(1 - \Upsilon_{sk}\right)\hat{P}_s \tag{49}$$

Note that if the price level increases, all non-cartel members increase their market shares. This increase is higher for smaller firms, as Υ_{sk} increases with size.

For cartel members, equilibrium markups at the first-order are as follows:

$$\hat{\mu}^{\mathcal{C}}_{sk} = \mu_{sk}\left(\frac{1}{\eta} - \frac{1}{\rho}\right)\left(\omega_{sk}\hat{\omega}_{sk} + \Delta\kappa \sum_{j\in\mathcal{C}\setminus\{k\}} \omega_{sj} + \kappa \sum_{j\in\mathcal{C}\setminus\{k\}} \omega_{sj}\hat{\omega}_{sj}\right) \tag{50}$$

as markups are distorted by the collusive behavior. Now, since $\kappa = 0$ at t we have:

$$\hat{P}^{\mathcal{C}}_{sk} = \mu_{sk}\left(\frac{1}{\eta} - \frac{1}{\rho}\right)\left(\omega_{sk}(\rho - 1)\left(\hat{P}_s - \hat{P}_{sk}\right) + \Delta\kappa \sum_{j\in\mathcal{C}\setminus\{k\}} \omega_{sj}\right) \tag{51}$$

and therefore

$$\hat{P}^{\mathcal{C}}_{sk} = \Upsilon_{sk}\hat{P}_s + \frac{1}{\rho - 1}\frac{\Upsilon_{sk}}{\omega_{sk}}\left(\omega_{s\mathcal{C}} - \omega_{sk}\right)\Delta\kappa \tag{52}$$

where $\omega_{s\mathcal{C}} := \sum_{j\in\mathcal{C}} \omega_{sj}$ is the total market share controlled by the cartel. Note that the first term is similar to that of non-cartel members. It captures the umbrella channel from higher prices in the sector, while the additional term captures the distortion arising from collusion. This distortion is larger the larger the cartel, and the more intense the collusion. The associated change in market shares is:

$$\hat{\omega}^{\mathcal{C}}_{sk} = (\rho - 1)\left(1 - \Upsilon_{sk}\right)\hat{P}_s - \frac{\Upsilon_{sk}}{\omega_{sk}}\left(\omega_{s\mathcal{C}} - \omega_{sk}\right)\Delta\kappa \tag{53}$$

As we have seen, non-cartel firms are all gaining market shares. Therefore, by construction, some cartel members must be losing market shares.

Given the definition of the sectoral price index, its first-order approximation yields:

$$\hat{P}_s = \sum_k \omega_{sk}\hat{P}_{sk} \tag{54}$$

Thus, aggregating price changes for both non-cartelized firms (eq. (47)) and cartelized firms (eq. (52)) the sectoral price is:

$$\hat{P}_s = \sum_{k\notin\mathcal{C}} \omega_{sk}\Upsilon_{sk}\hat{P}_s + \sum_{k\in\mathcal{C}} \omega_{sk}\Upsilon_{sk}\hat{P}_s + \sum_{k\in\mathcal{C}} \Upsilon_{sk}\frac{1}{\rho - 1}\left(\omega_{s\mathcal{C}} - \omega_{sk}\right)\Delta\kappa \tag{55}$$

or

$$\hat{P}_s = \hat{P}_s \sum_k \omega_{sk} \Upsilon_{sk} + \sum_{k \in \mathcal{C}} \Upsilon_{sk} \frac{1}{\rho - 1} \left(\omega_{s\mathcal{C}} - \omega_{sk} \right) \Delta\kappa$$

Solving for $\hat{P}_s$ yields:

$$\hat{P}_s = \frac{1}{1 - \sum_k \omega_{sk} \Upsilon_{sk}} \frac{1}{\rho - 1} \sum_{k \in \mathcal{C}} \Upsilon_{sk} \left(\omega_{s\mathcal{C}} - \omega_{sk} \right) \Delta\kappa \tag{56}$$

The sectoral price change is therefore a weighted average of the firms' overcharges, up to a multiplier effect via umbrella pricing, captured by the first fraction before the sum. Since $0 < \Upsilon_{sk} < 1$ for all s, k, and $\sum_k \omega_{sk} = 1$, we have $0 < \sum_k \omega_{sk} \Upsilon_{sk} < 1$. Therefore the price change is positive, which proves the first result. The second result follows from eq. (47) and eq. (52). As P_s increases, all prices go up, both for cartel and non-cartel firms. The third result follows from the fact that $\Upsilon_{sk} \in (0, 1)$ increases with firm size. Finally, for cartel members, notice that $\frac{\Upsilon_{sk}}{\omega_{sk}}$ decreases with size. To see this, let $a := (\rho - 1) \left(\frac{1}{\eta} - \frac{1}{\rho} \right)$ so that:

$$\frac{\Upsilon_{sk}}{\omega_{sk}} = \frac{a \mu_{sk}}{1 + a \omega_{sk} \mu_{sk}} \tag{57}$$

Therefore:

$$\frac{\partial \frac{\Upsilon_{sk}}{\omega_{sk}}}{\partial \omega_{sk}} = \frac{a \frac{\partial \mu_{sk}}{\partial \omega_{sk}} \left(1 + a \omega_{sk} \mu_{sk} \right) - a \mu_{sk} \times a \left(\mu_{sk} + \omega_{sk} \frac{\partial \mu_{sk}}{\partial \omega_{sk}} \right)}{\left(1 + a \omega_{sk} \mu_{sk} \right)^2} \tag{58}$$

$$\frac{\partial \frac{\Upsilon_{sk}}{\omega_{sk}}}{\partial \omega_{sk}} = \frac{a \left(\frac{\partial \mu_{sk}}{\partial \omega_{sk}} - a \mu_{sk}^2 \right)}{\left(1 + a \omega_{sk} \mu_{sk} \right)^2} \tag{59}$$

Now recall that $\frac{\partial \mu_{sk}}{\partial \omega_{sk}} = \mu_{sk}^2 \left(\frac{1}{\eta} - \frac{1}{\rho} \right)$ and therefore:

$$\frac{\partial \frac{\Upsilon_{sk}}{\omega_{sk}}}{\partial \omega_{sk}} = \frac{a \mu_{sk}^2 \left(\frac{1}{\eta} - \frac{1}{\rho} \right) (2 - \rho)}{\left(1 + a \omega_{sk} \mu_{sk} \right)^2} < 0 \tag{60}$$

Therefore $\frac{\Upsilon_{sk}}{\omega_{sk}}$ is decreasing with firm size if and only if $\rho > 2$. This is the case in all our quantitative analysis.

The proof of corollary 1 simply follows from the fact that in eq. (56) the impact on the price index is larger the more intense the collusion and the larger the market share controlled by the cartel.

The proof of corollary 2 follows from eq. (53). Notice that, everything else equal, as ω_{sk} tends to 0 the first term tends to $(\rho - 1) \hat{P}_s > 0$ while the second term tends to $-\left(\frac{\rho}{\eta} - 1 \right) \omega_{s\mathcal{C}} \Delta\kappa < 0$. Depending on the composition of the cartel, $\lim_{\omega_{sk} \to 0} \hat{\omega}_{sk}^{\mathcal{C}}$ can be either positive or negative. This is confirmed in our quantitative exercise. □

B.3 Collusion and Misallocation

The sectoral change in productivity is, by definition,

$$\hat{z}_s = \hat{\mu}_s - \hat{P}_s$$

Recall that $\mu_s = \left(\sum_k \omega_{sk}\mu_{sk}^{-1}\right)^{-1}$ and that $P_s = \left[\sum_{k=1}^{K_s} \left(P_{sk}\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}$. Therefore at the first order we have

$$\hat{z}_s = \sum_k \omega_{sk}\frac{\mu_s}{\mu_{sk}}\left(\hat{\mu}_{sk} - \hat{\omega}_{sk}\right) - \sum_k \omega_{sk}\hat{P}_{sk} \tag{61}$$

As there is no technological shocks at the firm level $\hat{\mu}_{sk} = \hat{P}_{sk}$ for all s, k and from eq. (45) we have $\hat{\omega}_{sk} = (1-\rho)\left(\hat{P}_{sk} - \hat{P}_s\right)$. The impact of collusion on sectoral productivity is

$$\hat{z}_s = \sum_k \omega_{sk}\frac{\mu_s}{\mu_{sk}}\left[\hat{P}_{sk} - (1-\rho)\left(\hat{P}_{sk} - \hat{P}_s\right)\right] - \sum_k \omega_{sk}\hat{P}_{sk} \tag{62}$$

Thus, rearranging the terms we have

$$\hat{z}_s = \sum_k \omega_{sk}\frac{\mu_s}{\mu_{sk}}\left[\rho\hat{P}_{sk} - (\rho-1)\hat{P}_s\right] - \sum_k \omega_{sk}\hat{P}_{sk} \tag{63}$$

$$\hat{z}_s = \sum_k \omega_{sk}\left(\frac{\mu_s}{\mu_{sk}} - 1\right)\hat{P}_{sk} + (\rho-1)\sum_k \omega_{sk}\frac{\mu_s}{\mu_{sk}}\left(\hat{P}_{sk} - \hat{P}_s\right) \tag{64}$$

B.4 Alternative Collusion Arrangements and Overcharges

As previously shown, in the case of symmetric collusion, distortions in both prices and quantities are larger for smaller cartel members. This is because, with a uniform collusion intensity, larger firms carry a relatively larger influence on the pricing decisions of the small firms. This effect can be obtained by considering alternative collusion forms. Recall that more generally the inverse markup is

$$\frac{1}{\tilde{\mu}_{sk}} = \frac{\rho-1}{\rho} + \left(\frac{1}{\eta} - \frac{1}{\rho}\right)\left(\omega_{sk} + \kappa_k \sum_{j\in\mathcal{C}\setminus\{k\}} \omega_{sj}\right) \tag{65}$$

where κ_k for $k \in \mathcal{C}$ is a collection of collusive intensities. And therefore for small given changes of collusion intensity $\Delta\kappa_k$ we have

$$\hat{\mu}_{sk} = \mu_{sk}\left(\frac{1}{\eta} - \frac{1}{\rho}\right)\left(\omega_{sk}\hat{\omega}_{sk} + \Delta\kappa_k \sum_{j\in\mathcal{C}\setminus\{k\}} \omega_{sj}\right) \tag{66}$$

Price changes take the general form

$$\begin{cases} \hat{P}_{sk} = \Upsilon_{sk}\hat{P}_s + \Theta_{sk} \\ \hat{\omega}_{sk} = (\rho-1)\left(1-\Upsilon_{sk}\right)\hat{P}_s - (\rho-1)\,\Theta_{sk} \end{cases} \tag{67}$$

where the overcharge is

$$\Theta_{sk} = \frac{1}{\rho-1}\frac{\Upsilon_{sk}}{\omega_{sk}}\left(\omega_{s\mathcal{C}} - \omega_{sk}\right)\Delta\kappa_k \tag{68}$$

if firm k joins the cartel and 0 otherwise. Notice that the sectoral price change is a weighted average of overcharges, times a multiplier

$$\hat{P}_s = \frac{1}{1-\sum_k \omega_{sk}\Upsilon_{sk}} \sum_{k\in\mathcal{C}} \omega_{sk}\Theta_{sk} \tag{69}$$

Consider a more general class of collusion arrangements of the form

$$\Delta\kappa_k = \psi(\omega_{sk})\psi_{\mathcal{C}}\Delta\kappa \tag{70}$$

where $\Delta\kappa$ controls the intensive margin of the collusion, $\psi(\omega_{sk})$ controls the "slope" of the effort sharing across members depending only on a member's initial market share, and $\psi_{\mathcal{C}}$ is a scaling factor common to all cartel members. For uniform symmetric collusions, $\psi(.)$=1 and $\psi_{\mathcal{C}} = 1$. Now consider a specific collusion arrangement characterized by

$$\begin{cases} \psi(\omega_{sk}) = \frac{\omega_{sk}}{\Upsilon_{sk}(\omega_{s\mathcal{C}}-\omega_{sk})} \\ \psi_{\mathcal{C}} = \sum_{k\in\mathcal{C}} \Upsilon_{sk}\frac{(\omega_{s\mathcal{C}}-\omega_{sk})}{\omega_{s\mathcal{C}}} \end{cases} \tag{71}$$

It follows from eq. (69) that such a cartel would increase the sectoral price level by exactly the same amount as a symmetric cartel with $\Delta\kappa$ as shown in eq. (56). As a result, it would have the exact same impact on non-cartel members. In addition, under such an arrangement, there will be less disparity in distortions within the cartel, as prices and quantities are now

$$\begin{cases} \hat{P}_{sk} = \Upsilon_{sk}\hat{P}_s + \frac{1}{\rho-1}\psi_{\mathcal{C}}\Delta\kappa \\ \hat{\omega}_{sk} = (\rho-1)\left(1-\Upsilon_{sk}\right)\hat{P}_s - \psi_{\mathcal{C}}\Delta\kappa \end{cases} \tag{72}$$

Under this arrangement, the change in prices for cartel members is now increasing with the size of the firm but the bulk of the overcharge, $\frac{1}{\rho-1}\psi_{\mathcal{C}}\Delta\kappa$, is the same across the cartel. Therefore, such cartels operate closer to the "fairness" principle considered in Bos and Harrington (2010).

B.5 Collusion and Cartel Stability

While collusion can raise cartel members' profits, the presence of short gains from defecting from the cartel arrangement threaten the ability of the cartel. Cartels can nevertheless be stable in a repeated game settings when participants can credibly threaten to punish defection (Abreu, 1988). We show in this section that our framework lends itself to the canonical analysis of cartel stability in a repeated game and we derive conditions i) for profits to increase after joining the cartel and ii) for stability when firms are patient enough.

Consider the change in log profits after a cartel $\mathcal{C}$ is formed

$$\hat{\Pi}_{sk}^{\mathcal{C}} = \log \Pi_{sk,t+dt}^{\mathcal{C}} - \log \Pi_{sk,t} \tag{73}$$

where there is no collusion at $t = 0$. We first show that there exist incentives to deviate, that is, $\hat{\Pi}_{sk}^{\mathcal{C}\setminus\{k\}} > \hat{\Pi}_{sk}^{\mathcal{C}}$. As there are no productivity shocks, and since profits can be written $\Pi_{sk} = (\mu_{sk} - 1)\frac{W}{z_{sk}} q_{sk}$, after taking logs and differentiating, we have

$$\hat{\Pi}_{sk}^{\mathcal{C}} = \frac{\mu_{sk}}{\mu_{sk} - 1}\hat{\mu}_{sk} + \hat{q}_{sk} \tag{74}$$

On the other hand combining eq. (3) and eq. (6) and taking log changes we have

$$\hat{q}_{sk} = \rho\left(\hat{P}_s^{\mathcal{C}} - \hat{P}_{sk}\right) - \eta\hat{P}_s^{\mathcal{C}} \tag{75}$$

Therefore the change in profits is

$$\hat{\Pi}_{sk}^{\mathcal{C}} = \varepsilon_{sk}\hat{\mu}_{sk} + \rho\left(\hat{P}_s^{\mathcal{C}} - \hat{P}_{sk}\right) - \eta\hat{P}_s^{\mathcal{C}} \tag{76}$$

Finally, as $\hat{\mu}_{sk} = \hat{P}_{sk}$ in the absence of technological shocks and using the notation for the overcharge introduced in eq. (68) we have

$$\hat{\Pi}_{sk}^{\mathcal{C}} = \left[\rho - \eta - \Upsilon_{sk}\left(\rho - \varepsilon_{sk}\right)\right]\hat{P}_s^{\mathcal{C}} - \left(\rho - \varepsilon_{sk}\right)\Theta_{sk} \tag{77}$$

Notice that, for a given sectoral price increase, as the term in brackets decreases with size, the upper bound gets tighter the larger the firm.

Participation constraint. For non-cartel members, the change in log profits is always positive, as $\Upsilon_{sk} < 1$ and $\varepsilon_{sk} \in (\eta, \rho)$ for all k, we have

$$\hat{\Pi}_{sk} = \left[\rho - \eta - \Upsilon_{sk}\left(\rho - \varepsilon_{sk}\right)\right]\hat{P}_s^{\mathcal{C}} > 0 \tag{78}$$

In addition, as both Υ_{sk} and $\rho - \varepsilon_{sk}$ are increasing with size, the term in brackets decreases with size, that is, smaller non-cartel firms exhibit a larger proportional increase in umbrella profits when the cartel forms.

For cartel members, recall that from eq. (77), the change in profits is

$$\hat{\Pi}_{sk}^{\mathcal{C}} = \left[\rho - \eta - \Upsilon_{sk}\left(\rho - \varepsilon_{sk}\right)\right]\hat{P}_s^{\mathcal{C}} - \left(\rho - \varepsilon_{sk}\right)\Theta_{sk}$$

Two channels are affecting profit changes: i) by joining the cartel, firm k contributes to further raising the price level, increasing its profits; at the same time, ii) this increase comes at a personal cost in terms of lost market shares. The first term capture the first channel and is decreasing with size. Regarding the second term, the factor in front of the overcharge is increasing with size. Firm k profits from joining the cartel compared to the baseline equilibrium if and only if

$$\Theta_{sk} < \left[\frac{\rho - \eta}{\rho - \varepsilon_{sk}} - \Upsilon_{sk}\right]\hat{P}_s^{\mathcal{C}} \tag{79}$$

Incentive compatibility. The cartel is sustainable under a punishment trigger strategy if there exists δ such that

$$\frac{1}{1-\delta}\hat{\Pi}_{sk}^{\mathcal{C}} > \hat{\Pi}_{s}^{\mathcal{C}\setminus\{k\}} \tag{80}$$

To analyze the incentives for firms to join the cartel, suppose that that the cartel is not viable if firm k does not join. Then the counterfactual is the initial oligopolistic equilibrium, that is, profits do not change. If the cartel is viable without firm k joining, then the counterfactual profit is

$$\hat{\Pi}_{sk}^{\mathcal{C}\setminus\{k\}} = \left[\rho - \eta - \Upsilon_{sk}\left(\rho - \varepsilon_{sk}\right)\right]\hat{P}_s^{\mathcal{C}\setminus\{k\}} \tag{81}$$

Notice that

$$\hat{\Pi}_{sk}^{\mathcal{C}} = \hat{\Pi}_{sk}^{\mathcal{C}\setminus\{k\}}\frac{\hat{P}_s^{\mathcal{C}}}{\hat{P}_s^{\mathcal{C}\setminus\{k\}}} - \left(\rho - \varepsilon_{sk}\right)\Theta_{sk} \tag{82}$$

Therefore colluding profit incentives require

$$\Theta_{sk} < \left[\frac{\rho - \eta}{\rho - \varepsilon_{sk}} - \Upsilon_{sk} \right] \left[\hat{P}_{s}^{\mathcal{C}} - (1 - \delta)\, \hat{P}_{sk}^{\mathcal{C} \setminus \{k\}} \right] \tag{83}$$

This constraint is therefore always more binding than the participation constraint derived above. In fact this constraint converges to the participation constraint from below as cartel members become infinitely patient, i.e. $\delta \to 1$. Conversely, if cartel members are perfectly impatient, the term in the right bracket reduces to the sectoral price increment due to member k joining the cartel:

$$\hat{P}_{sk}^{\mathcal{C}} - \hat{P}_{sk}^{\mathcal{C} \setminus \{k\}} = \frac{1}{\rho - 1} \frac{1}{1 - \sum_k \omega_{sk} \Upsilon_{sk}} \left[\Upsilon_{sk} \left(\omega_{s\mathcal{C}} - \omega_{sk} \right) + \omega_{sk} \sum_{j \in \mathcal{C} \setminus \{k\}} \Upsilon_{sj} \right] \Delta\kappa \tag{84}$$

This additional price increase is decomposed into two channels: i) the influence of other cartel members on firm k and ii) the influence of firm k on each other cartel member $j \in \mathcal{C} \setminus \{k\}$. Finally, notice that this upper bound is always strictly positive and that the constraint is no longer necessarily monotonous but will depend on how collusive effort is shared in the cartel.

B.6 Bertrand Competition

We can alternatively solve the model under the assumption that firms engage in a static game of Bertrand Competition. One can combine the inverse demand functions eq. (3) and eq. (6):

$$q_{sk} = P_{sk}^{-\rho} \left(\sum_{k} P_{sk}^{1-\rho} \right)^{\frac{1}{\eta} - \frac{1}{\rho}} c P^{\eta}$$

The firm chooses its prices subject to the above constraint. This yields the first-order condition:

$$q_{sk} + \left(P_{sk} - \frac{W}{z_{sk}} \right) \frac{\partial q_{sk}}{\partial P_{sk}} = 0 \tag{85}$$

The derivative of the constraint with respect to the firm's price gives:

$$\frac{\partial q_{sk}}{\partial P_{sk}} = -\rho \frac{q_{sk}}{P_{sk}} + (\rho - \eta) \omega_{sk} \frac{q_{sk}}{P_{sk}}$$

Plugging this equation back into eq. (85) and rearranging yields:

$$P_{sk} = \frac{\rho - (\rho - \eta)\omega_{sk}}{\rho - (\rho - \eta)\omega_{sk} - 1} \frac{W}{z_{sk}} \tag{86}$$

In the competitive Nash-Bertrand case, the demand elasticities are given by

$$\varepsilon\left(\omega_{sk}\right) \quad = \quad \rho - (\rho - \eta)\omega_{sk} \tag{87}$$

The elasticities are now sales-weighted arithmetic means instead of sales-weighted harmonic means as in the Cournot case. They are thus at least as large as in the Cournot case. The markups in the Bertrand setting are thus typically smaller than in the Cournot setting. In the cartel equilibrium, the demand elasticities of the cartel members are given by:

$$\varepsilon\left(s\right) = \rho - (\rho - \eta)\left(\omega_{sk} + \sum_{j \in \mathcal{C} \setminus \{k\}} \kappa_{kj}\omega_{sj}\right) \tag{88}$$

B.7 Consumption-Equivalent Welfare

The lifetime utility of the representative consumer in the cartelized economy is given by:

$$W \equiv \sum_{t=0}^{\infty} \beta^t U\Big(C_t, L_t\Big) = \sum_{t=0}^{\infty} \beta^t \left(\ln C_t - \frac{L_t^{1+\psi}}{1+\psi}\right) \tag{89}$$

where β is the discount factor, C_t denotes the consumption of the household in period t, L_t is its labor supply and ψ is the inverse of the Frisch elasticity of labor supply. Capital is accumulated following the standard law of motion $K_{t+1} = K_t(1 - \tau) + I_t$ where τ is the depreciation rate of capital and I_t is investment.

The consumption-equivalent welfare change is the change in consumption ΔC that is necessary to keep the consumer indifferent between the cartelized allocation and the competitive allocation. It is such that:

$$\sum_{t=0}^{\infty} \beta^t U\Big(C_t^{\text{Cartel}}(1 + \Delta C), L_t^{\text{Cartel}}\Big) = \sum_{t=0}^{\infty} \beta^t U\Big(C_t^{\text{Comp}}, L_t^{\text{Comp}}\Big) \tag{90}$$

Given the utility of the consumer, ΔC is given by:

$$\Delta C = \exp\Big((W^{\text{Cartel}} - W^{\text{Comp}})(1 - \beta)\Big) - 1 \tag{91}$$

This welfare measure takes into account the cost of the transition to the competitive steady-state.

C Additional Evidence on Cartel Composition

C.1 Additional Results

Table A9 investigates the characteristics of both colluding firms and firms that classify as competitive. Colluding firms have a much higher market share —their market share averages 3.4% versus 0.07% for non-colluding firms, sell more, spend more on intermediate goods, have more employees, are more capital-intensive, are more productive —as measured by labor productivity —and are more likely to be exporting firms. Finally, Table A10 shows that firms that are top producers in their sector or industry are more likely to be anticompetitive firms.

C.2 Theoretical Literature

As reviewed in Asker and Nocke (2021), the theoretical literature on the endogenous choice of cartel formation remains scarce with the recent exception of Bos and Harrington (2010) and Bos and Harrington (2015) who consider cartel formation across firms that are ex ante heterogenous in their capacities. The important result is that larger firms are more likely to find it profitable to join a cartel because of a trade-off: joining the cartel will allow them to increase their markups and prices but it will also lead to a decrease in their sales. The latter effect is larger for smaller firms with a low capacity, so that "we should not expect a cartel to include very small firms" (Bos and Harrington, 2010). Bos and Harrington (2015) include a competition authority that can detect and convict cartels. They find that antitrust enforcement deters small firms from joining a cartel.

C.3 Empirical Literature

While we are not aware of any other empirical test of our results in Section 4.1, some authors have found that the cumulative market share of cartel members is extremely large, suggesting that cartel members are the top producers in their industry. For instance, Combe and Monnier (2012) find that the average cartel market share in their sample is 80% and that two-thirds have a cumulated market share higher than 75%.[62] Similarly, Zimmerman and Connor (2005) report an average cartel market share of 85%, while Combe and Monnier (2012) report an average and a median cartel market share of 75%. Harrington Jr et al. (2015) document that the German cement cartel that operated from 1991 until 2002 was made up of the six largest cement firms which controlled 86% of the market.

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[62] This sample includes the 48 cartels for which they were able to compute the cumulated cartel market share.

D Sectoral Markups and Concentration

D.1 Non-Cartelized Sectors

The sectoral markup is given by:

$$\mu_s = \left(\sum_{k=1}^{K_s} \mu_{sk}^{-1} \omega_{sk} \right)^{-1} \tag{92}$$

In non-cartelized sectors, (inverse) firm-level markups under Cournot competition are given by:

$$\mu_{sk}^{-1} = \frac{\rho - 1}{\rho} + \left(\frac{\eta - 1}{\eta} - \frac{\rho - 1}{\rho} \right) \omega_{sk}$$

Plugging that into the previous equation yields:

$$\mu_s^{-1} = \sum_{k=1}^{K_s} \left(\frac{\rho - 1}{\rho} + (\frac{\eta - 1}{\eta} - \frac{\rho - 1}{\rho}) \omega_{sk} \right) \omega_{sk}$$

$$\mu_s^{-1} = \frac{\rho - 1}{\rho} + \sum_{k=1}^{K_s} (\frac{\eta - 1}{\eta} - \frac{\rho - 1}{\rho}) \omega_{sk}^2$$

$$\mu_s^{-1} = \frac{\rho - 1}{\rho} + (\frac{\eta - 1}{\eta} - \frac{\rho - 1}{\rho}) \mathrm{HHI}_s$$

$$\mu_s^{-1} = \frac{\rho - 1}{\rho} - \frac{\frac{\rho}{\eta} - 1}{\rho} \mathrm{HHI}_s \tag{93}$$

Burstein et al. (2020) estimate the following equation:

$$\mu_s^{-1} = \alpha + \beta \mathrm{HHI}_s + \epsilon_{st} \tag{94}$$

where $\alpha := \frac{\rho-1}{\rho}$ and $\beta := -\frac{\frac{\rho}{\eta}-1}{\rho}$.

D.2 Cartelized Sectors

Firm-level markups of cartel-members are now given by:

$$\mu_{sk}^{-1} = \frac{\rho - 1}{\rho} + \left(\frac{\eta - 1}{\eta} - \frac{\rho - 1}{\rho} \right) \left(\omega_{sk} + \kappa \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj} \right)$$

while markups of non-cartel members are defined as in the previous section.

We now have to keep track of cartel and non-cartel members when computing the sectoral markup:

$$\mu_s^{-1} = \sum_{k=1}^{K_s} \mu_{sk}^{-1} \omega_{sk}$$

$$\mu_s^{-1} = \sum_{k=1}^{K_s^{\text{comp}}} \mu_{sk}^{-1} \omega_{sk} + \sum_{k=1}^{K_s^{\text{cartel}}} \mu_{sk}^{-1} \omega_{sk} \tag{95}$$

Replacing non-cartel members' and cartel members' markups yields:

$$\begin{aligned} \mu_s^{-1} = & \sum_{k=1}^{K_s^{\text{comp}}} \left(\frac{\rho-1}{\rho} + \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho} \right) \omega_{sk} \right) \omega_{sk} \\ & + \sum_{k=1}^{K_s^{\text{cartel}}} \left(\frac{\rho-1}{\rho} + \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho} \right) \left(\omega_{sk} + \kappa \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj} \right) \right) \omega_{sk} \end{aligned}$$

We now group terms:

$$\begin{aligned} \mu_s^{-1} = & \sum_{k=1}^{K_s^{\text{comp}}} \left(\frac{\rho-1}{\rho} + \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho} \right) \omega_{sk} \right) \omega_{sk} \\ & + \sum_{k=1}^{K_s^{\text{cartel}}} \left(\frac{\rho-1}{\rho} + \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho} \right) \omega_{sk} \right) \omega_{sk} \\ & + \sum_{k=1}^{K_s^{\text{cartel}}} \left(\kappa \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho} \right) \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj} \right) \omega_{sk} \end{aligned}$$

Simplifying:

$$\mu_s^{-1} = \frac{\rho-1}{\rho} - \frac{\frac{\rho}{\eta}-1}{\rho} \text{HHI}_s + \sum_{k=1}^{K_s^{\text{cartel}}} \left(\kappa \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho} \right) \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj} \right) \omega_{sk}$$

$$\mu_s^{-1} = \frac{\rho-1}{\rho} - \frac{\frac{\rho}{\eta}-1}{\rho} \text{HHI}_s + \kappa \left(\frac{\eta-1}{\eta} - \frac{\rho-1}{\rho} \right) \sum_{k=1}^{K_s^{\text{cartel}}} \omega_{sk} \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj}$$

$$\mu_s^{-1} = \frac{\rho-1}{\rho} - \frac{\frac{\rho}{\eta}-1}{\rho} \text{HHI}_s - \kappa \frac{\frac{\rho}{\eta}-1}{\rho} \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj} \omega_{s\mathcal{C}}$$

which is a modified version of Burstein et al. (2020). We rewrite it as:

$$\mu_s^{-1} = \frac{\rho-1}{\rho} - \frac{\frac{\rho}{\eta}-1}{\rho} \left(\text{HHI}_s + \kappa \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj} \omega_{s\mathcal{C}} \right) \tag{96}$$

In regression form:

$$\mu_s^{-1} = \alpha + \beta \mathrm{HHI}_s + \gamma \sum_{j \in \mathcal{C} \setminus \{k\}} \omega_{sj} \omega_{s\mathcal{C}} + \varepsilon_{st} \tag{97}$$

where α and β are defined as before, and $\gamma := -\kappa \frac{\frac{\rho}{\eta} - 1}{\rho}$. We rely on eq. (94) instead of eq. (97) to recover η. We target a value of $\hat{\beta} = -0.44$ for non-cartelized sectors to be consistent with Burstein et al. (2020).

E Identification of Model Parameters

To better understand whether the chosen moments help us identify the model parameters, we compute the Jacobian matrix of the baseline model. Each entry of the matrix reports the percentage change in each moment following a one percent increase in the value of each parameter. These changes are evaluated at the baseline calibration values. The matrix is displayed in Figure A6. We now discuss how the moments react to different parameter changes:

> (i) An increase in κ affects the ability of firms to charge higher markups, affecting the amount of overcharge relative to the competitive equilibrium. This overcharge is computed for each cartel as the change in the cartel markup. The cartel markup is computed as averages across cartel members in each equilibrium. We rely on arithmetic averages of cartel member overcharges as the harmonic mean is smaller. This means that our estimate of κ is conservative because a larger κ would be needed to match a target computed using harmonic averages. The overcharge is then defined as the median overcharge across cartels.
>
> (ii) An increase in the elasticity of substitution within sectors ρ increases the relative demand of more productive firms that charge lower prices, which increases their market share and increases the aggregate markup.
>
> (iii) The estimated slope parameter $\hat{\beta}$ helps identify η conditionnal on ρ. Indeed, from eq. (94), $\eta = \frac{\rho}{1-\beta\rho}$.
>
> (iv) The sales concentration data moments are sensitive to a change in the Pareto shape parameter ξ. When ξ increases, the productivity distribution becomes less skewed and firms are therefore more homogeneous. This decreases the fraction of firms selling less than their industry average and increases the fraction of total sales captured by relatively more productive firms.
>
> (v) The geometric parameter σ is identified by matching the median number of firms per sector. When σ increases, the number of firms decreases, which ends up affecting sales concentration, the cartel overcharge and the aggregate markup.
>
> (vi) The geometric parameter ζ is identified by matching the median number of cartel members. When this parameter decreases, the median number of cartel members increases, thereby affecting sales concentration and the cartel overcharge. Given its low value, a one percent change is not enough to generate changes in the *median* number of cartel members.

F Additional Tables

Table A1: Cartels by Sector (2007)

NAF (1)	Sector (2)	Sales Share (3)	VA Share (4)	# Cartels (5)	# Colluding Firms (6)
01-05	Agriculture, hunting, forestry, fishing	0.0010	0.0013		
10-14	Mining and quarrying	0.0029	0.0038		
15-16	Food products, beverages and tobacco	0.0458	0.0419	4	24
17-19	Textiles, leather and footwear	0.0087	0.0093		
20	Wood and wood products	0.0043	0.0046		
21-22	Pulp, paper, publishing and printing	0.0173	0.0194	1	1
23	Coke	0.0209	0.0162		
24	Chemicals	0.0405	0.0378		
25	Rubber and plastics	0.0149	0.0151	2	4
26	Other non-metallic mineral prod.	0.0097	0.0113		
27-28	Basic metals and fabricated metal prod.	0.0341	0.0362	1	2
29	Machinery and equipment n.e.c.	0.0245	0.0259	1	2
30-33	Electrical and optical equipment	0.0270	0.0299		
34-35	Transport equipment	0.0554	0.0383		
36-37	Other manufacturing n.e.c	0.0098	0.0090		
40-41	Electricity, gas and water supply	0.0335	0.0350		
45	Construction	0.0693	0.0866	1	1
50-52	Wholesale and retail	0.3473	0.1930	11	22
55	Hotels and restaurants	0.0213	0.0340		
60-63	Transport and storage	0.0511	0.0617	4	20
64	Post and telecommunications	0.0250	0.0468	1	1
70	Real estate activities	0.0187	0.0315		
71-74	Renting and business activities	0.0861	0.1532	2	7
80	Education	0.0020	0.0039		
85	Health and social work	0.0100	0.0209	1	2
90-93	Other service activities	0.0189	0.0334		

Notes: The sales share column represents sector-level sales in total sales in 2007. The VA share column represents sector-level value-added in total value-added in 2007. The number of colluding firms in a cartel in column (6) can be equal to one because some firms were not matched to the administrative data and are therefore dropped.

Table A2: Anticompetitive Firm Premium

	ln Sales			Market Share			ln Employment			ln Labor Productivity		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: All cartels												
$\mathbb{1}_{\text{Collude}}$	4.040***	3.582***	3.002***	4.400***	4.297***	4.028***	3.306***	2.998***	2.526***	0.478***	0.364***	0.318***
	(0.092)	(0.092)	(0.082)	(0.548)	(0.542)	(0.473)	(0.084)	(0.084)	(0.075)	(0.027)	(0.024)	(0.022)
# Obs.	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544
R^2	0.002	0.177	0.315	0.005	0.036	0.198	0.002	0.096	0.215	0.000	0.091	0.152
Panel B: Price-fixing cartels												
$\mathbb{1}_{\text{Collude}}$	3.912***	3.268***	2.881***	2.923***	2.822***	2.720***	2.940***	2.546***	2.301***	0.575***	0.445***	0.364***
	(0.149)	(0.140)	(0.124)	(0.397)	(0.391)	(0.375)	(0.131)	(0.122)	(0.110)	(0.037)	(0.033)	(0.033)
# Obs.	12,450,922	12,450,922	12,450,922	12,450,922	12,450,922	12,450,922	12,450,922	12,450,922	12,450,922	12,450,922	12,450,922	12,450,922
R^2	0.000	0.176	0.315	0.000	0.033	0.199	0.000	0.095	0.215	0.000	0.091	0.151
Two-digit Sector × Year FE	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No
Four-digit Industry × Year FE	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: The values displayed are for the period 1994-2007. Sales and value-added are in thousands of euros. Labor productivity is real value-added (deflated by 2-digit price indices) divided by the number of workers. Labor is the number of workers. The capital-labor ratio is expressed in real terms where capital has been deflated. Intermediates is the value of expenditures on intermediate goods in thousands of euros. All cartels are included in Panel A while cartels that do not fix prices directly have been dropped from the sample in Panel B.

Table A3: Labor Productivity and Sales Dispersion: Non-Cartel versus Cartel Members

	Non-Cartel Members			Cartel Members		
Moment	Mean (1)	Std. Dev. (2)	IQ Range (3)	Mean (4)	Std. Dev. (5)	IQ Range (6)
Panel A: Labor productivity						
Median	3.765	0.450	0.482	4.474	0.935	1.133
IQ range	0.722	0.316	0.250	0.389	0.347	0.666
90-10 percentile range	1.463	0.550	0.503	0.531	0.527	0.861
95-5 percentile range	1.971	0.699	0.675	0.572	0.540	0.945
Panel B: Sales						
Median	6.623	1.264	1.56	10.845	2.347	2.311
IQ range	1.989	0.835	0.821	1.197	1.149	1.788
90-10 percentile range	3.774	1.394	1.551	1.562	1.371	2.422
95-5 percentile range	4.828	1.700	1.995	1.625	1.416	2.839

Notes: This table summarizes firm-level labor productivity and domestic sales distribution moments across four-digit industries and across cartels. Rows correspond to moments of within-industry and within-cartel producer productivity or domestic sales distributions; columns show the across-industry and across-cartel mean and dispersion of these moments. IQ range is the interquartile range.

Table A4: Dispersion within the Manufacture of Plastic Components for Construction

	Labor Productivity		Log Sales	
	Non-Cartel Members (1)	Cartel Members (2)	Non-Cartel Members (3)	Cartel Members (4)
Median	4.758	5.585	7.695	10.516
IQ range	0.497	0.183	2.140	1.116
90-10 percentile range	0.984	0.183	4.135	1.116
95-5 percentile range	1.404	0.183	5.107	1.116

Notes: The industry considered is 252E, which corresponds to "Manufacture of plastic components for construction". There are two cartels in this industry in 2007 (Decisions "10D39" and "17D20") The figures are obtained by taking the firm mean of sales, value-added and labor productivity. We then compute the relevant ratios for each cartel case. Labor productivity is the ratio of value-added deflated by 2-digit price indices to the number of employees.

Table A5: Non-targeted Moments

Moments	**Data**	**Model**	**Source**
Cartel premium (sales)	4.040	3.214	French data
Cartel premium (employment)	3.306	3.006	French data
Cartel premium (labor productivity)	0.478	0.208	French data
Cartel premium (market share)	4.400	5.750	French data
Standard deviation of log sales	1.391	1.366	French data
Standard deviation of log employment	1.165	1.354	French data

Table A6: Markup Distribution

	Unconditional markup distribution		Sectoral markup distribution	
	Benchmark (1)	Competitive economy (2)	Benchmark (3)	Competitive economy (4)
p50	1.109	1.109	1.173	1.160
p75	1.110	1.109	1.215	1.198
p90	1.112	1.111	1.292	1.262
p95	1.116	1.115	1.381	1.334
p99	1.262	1.148	1.727	1.552
SD log	0.023	0.011	0.078	0.069
log p95/p50	0.006	0.005	0.163	0.140

Notes: The table reports moments of the markup distribution. Columns 1 and 2 report moments of the unconditional distribution where markups are pooled over all sectors. Columns 3 and 4 report moments of the markup distribution defined at the sector-level. Columns 1 and 3 report moments for the benchmark economy with cartels whereas columns 2 and 4 consider an economy with no cartels.

Table A7: Importance of the Umbrella Pricing Effect

	Benchmark (1)	No umbrella pricing effect (2)
Panel A: Aggregate productivity gains, in %		
$A_{\text{cartel}} \rightarrow A_{\text{comp}}$	1.11	1.14
$A \rightarrow A_{\text{eff}}$	3.67	3.67
Distance to efficient allocation	−30.34	−30.98
Panel B: Aggregate welfare gains		
$\mathcal{M}_{\text{cartel}} \rightarrow \mathcal{M}_{\text{comp}}$ (in pp)	−1.54	−1.44
$C_{\text{cartel}} \rightarrow C_{\text{comp}}$ (in %)	2.52	2.50
$K_{\text{cartel}} \rightarrow K_{\text{comp}}$ (in %)	4.11	3.99
$Y_{\text{cartel}} \rightarrow Y_{\text{comp}}$ (in %)	2.84	2.80
$L_{\text{cartel}} \rightarrow L_{\text{comp}}$ (in %)	0.53	0.49
$\mathcal{W}_{\text{cartel}} \rightarrow \mathcal{W}_{\text{comp}}$ (in %)	2.00	2.01

Notes: The table displays the aggregate productivity gains (rows 1 to 3) and the change (in points) in the level of the aggregate markup (row 4) resulting from eliminating cartels. The figures are obtained by comparing the relevant variables in the cartel equilibrium to that in the competitive Nash-Cournot equilibrium (row 1) and efficient allocation (row 2). The efficient allocation corresponds to the equilibrium without markup dispersion. The distance to the efficient allocation computed in row 3 is the ratio of the first two rows. In column 2, the markups of non-cartel members are held constant to their level in the cartel equilibrium.

Table A8: Estimation of κ

Sample	Inverse Markup					
	All cartels			Price-fixing cartels		
	(1)	(2)	(3)	(4)	(5)	(6)
Firm's Market Share	-0.531***	-0.140	-0.130	-0.682***	0.149	0.1598
	(0.176)	(0.188)	(0.190)	(0.188)	(0.325)	(0.325)
Cartel's Market Share		-0.320***	-0.326***		-0.320***	-0.496***
		(0.052)	(0.051)		(0.162)	(0.163)
Intercept	0.704***	0.729***	0.729***	0.684***	0.706***	0.705***
	(0.009)	(0.008)	(0.008)	(0.013)	(0.014)	(0.014)
Implied κ		0.70	0.71		1.42	1.48
Sum Coefficients		-0.46	-0.46		-0.35	-0.34
Ratio Coefficients		-0.63	-0.63		-0.50	-0.48
Year FE	No	No	Yes	No	No	Yes
# Observations	2,235	2,235	2,235	931	931	931
R-sq.	0.0575	0.1057	0.1147	0.0476	0.0939	0.1022

Notes: Standard errors clustered at the firm level. * significant at 10%, ** significant at 5%, *** significant at 1%. The collusion intensity is estimated following eq. (25) described in the text. The dependent variable is the firm's labor share. The cartel market share variable is the sum of the market shares of all firms that belong to the same cartel-industry pair. The sample in columns (4)-(6) consists of cartels involved in price-fixing and excludes non price-fixing cartels.

Table A9: Anticompetitive Firms are Larger

	Anticompetitive Firms				Competitive Firms			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Market Share (%)	3.43	10.79	0	100	0.07	0.92	0	100
Sales	295,277	1,851,776	10	36,700,000	2,070	56,499	1	45,600,000
Value-added	118,799	988,271	4	18,400,000	599	14,206	1	9,926,973
ln Labor Productivity	3.87	0.65	0.097	8.36	3.49	0.64	-2.8	9.52
Labor	1402	13,014	1	295,030	12	156	1	86,587
ln Wage	3.6	0.4	0.61	7.45	3.2	0.6	-2.4	8.6
ln Capital/Labor ratio	2.25	1.25	-2.04	6.47	1.71	1.24	-2.16	10.3
Intermediates	181,175	1,055,268	4	28,900,000	1479	45,876	1	39,800,000
# Obs.	10,721				12,441,919			
# Firms	907				2,167,168			
# Exporters	613				232,316			

Notes: The values displayed are for the period 1994-2007. Sales and value-added are in thousands of euros. Labor productivity is real value-added (deflated by 2-digit price indices) divided by the number of workers. Labor is the number of workers. The capital-labor ratio is expressed in real terms where capital has been deflated. Intermediates is the value of expenditures on intermediate goods in thousands of euros.

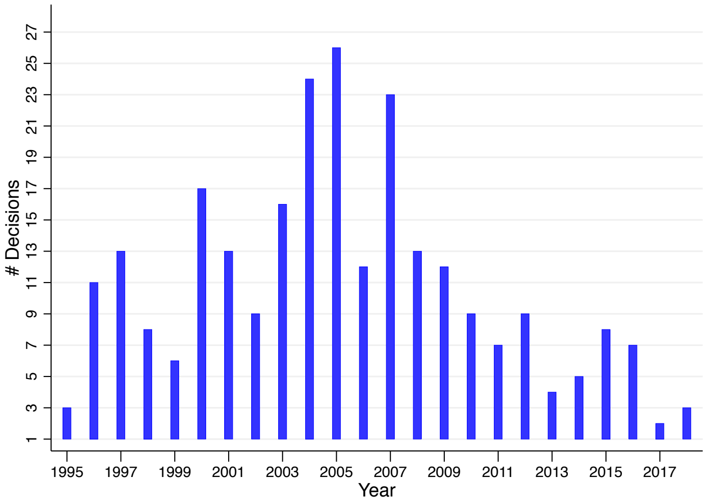
Table A10: Anticompetitive Firms and Firm Rank

	Dummy Anticompetitive Firm					
	(1)	(2)	(3)	(4)	(5)	(6)
ln Rank Market Share	-0.0003***	-0.0003***	-0.0005***			
	(0.0000)	(0.0000)	(0.0000)			
$\mathbb{1}_{\text{Top 4 Industry}}$				0.0163***	0.0163***	0.0164***
				(0.0015)	(0.0015)	(0.0015)
2-Digit Sector × Year FE	No	Yes	No	No	Yes	No
4-Digit Industry × Year FE	No	No	Yes	No	No	Yes
# Observations	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544	12,452,544
R-sq.	0.0012	0.0021	0.0186	0.0036	0.0045	0.0209

Notes: This table regresses a dummy variable taking the value of one if a firm is anticompetitive on two measures of the rank of firms in their 4-digit industry. ln Rank Market Share is the log rank of the firm in its industry according to its market share. $\mathbb{1}_{\text{Top 4 Industry}}$ is a dummy variable equal to one if a firm is one the top 4 firms in its industry.

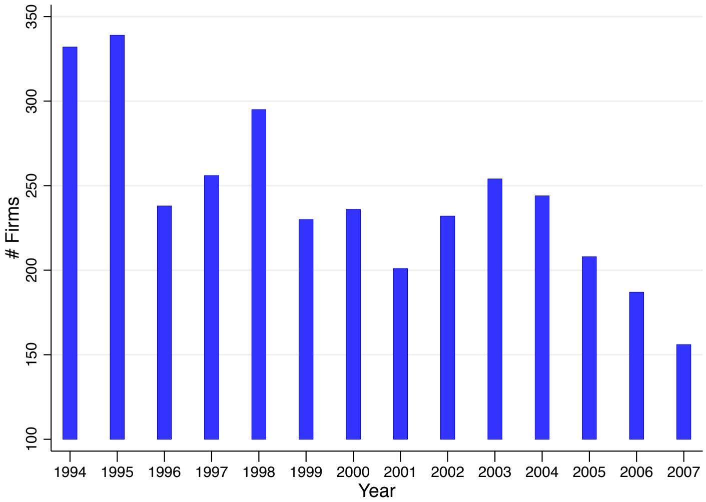
G Additional Figures

Figure A1: Number of Decisions per Year



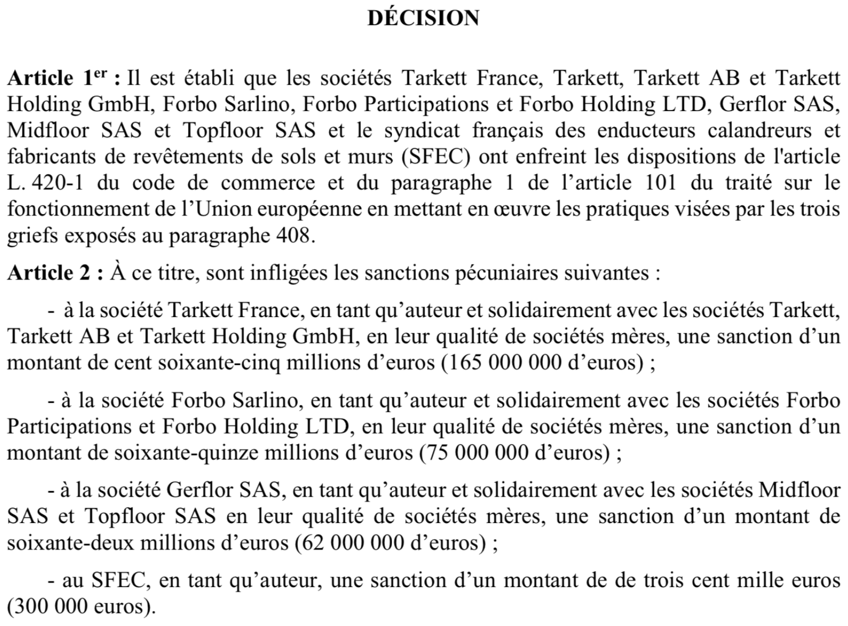
Data Source: Authors.

Figure A2: Number of Anti-competitive Firms per Year



Data Source: Authors.

Figure A3: Example of Decision File (17d20): Firms' Identity



DÉCISION

Article 1er : Il est établi que les sociétés Tarkett France, Tarkett, Tarkett AB et Tarkett Holding GmbH, Forbo Sarlino, Forbo Participations et Forbo Holding LTD, Gerflor SAS, Midfloor SAS et Topfloor SAS et le syndicat français des enducteurs calandreurs et fabricants de revêtements de sols et murs (SFEC) ont enfreint les dispositions de l'article L. 420-1 du code de commerce et du paragraphe 1 de l'article 101 du traité sur le fonctionnement de l'Union européenne en mettant en œuvre les pratiques visées par les trois griefs exposés au paragraphe 408.

Article 2 : À ce titre, sont infligées les sanctions pécuniaires suivantes :

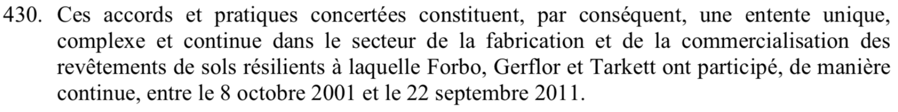
- à la société Tarkett France, en tant qu'auteur et solidairement avec les sociétés Tarkett, Tarkett AB et Tarkett Holding GmbH, en leur qualité de sociétés mères, une sanction d'un montant de cent soixante-cinq millions d'euros (165 000 000 d'euros) ;

- à la société Forbo Sarlino, en tant qu'auteur et solidairement avec les sociétés Forbo Participations et Forbo Holding LTD, en leur qualité de sociétés mères, une sanction d'un montant de soixante-quinze millions d'euros (75 000 000 d'euros) ;

- à la société Gerflor SAS, en tant qu'auteur et solidairement avec les sociétés Midfloor SAS et Topfloor SAS en leur qualité de sociétés mères, une sanction d'un montant de soixante-deux millions d'euros (62 000 000 d'euros) ;

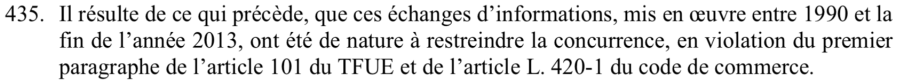
- au SFEC, en tant qu'auteur, une sanction d'un montant de de trois cent mille euros (300 000 euros).

Figure A4: Example of Decision File (17d20): Duration of Cartel



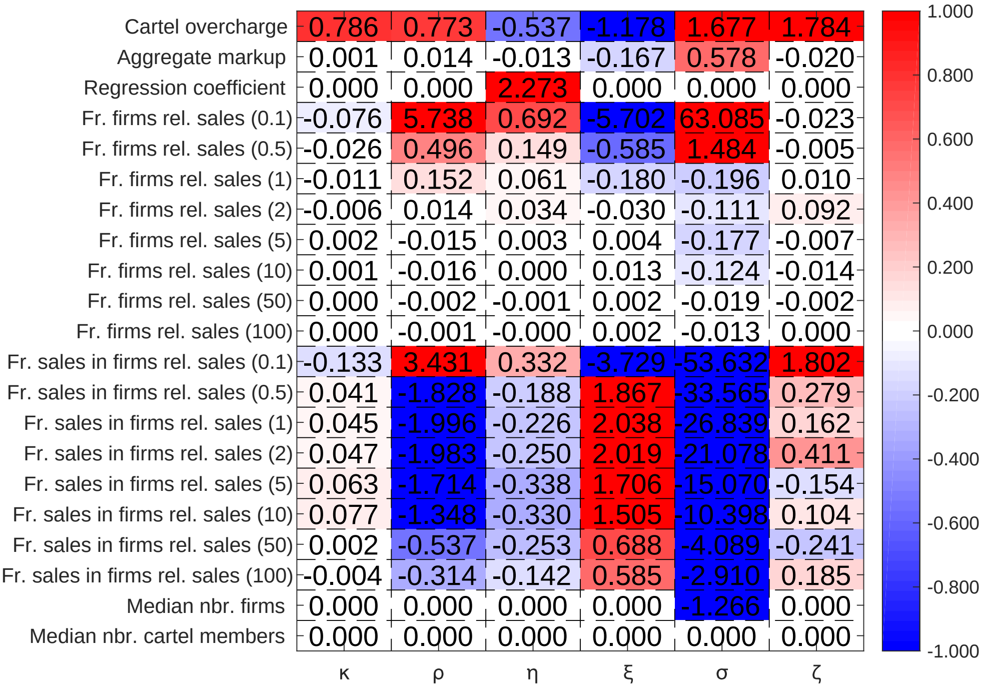
430. Ces accords et pratiques concertées constituent, par conséquent, une entente unique, complexe et continue dans le secteur de la fabrication et de la commercialisation des revêtements de sols résilients à laquelle Forbo, Gerflor et Tarkett ont participé, de manière continue, entre le 8 octobre 2001 et le 22 septembre 2011.

Figure A5: Example of Decision File (17d20): Type of Infringement



435. Il résulte de ce qui précède, que ces échanges d'informations, mis en œuvre entre 1990 et la fin de l'année 2013, ont été de nature à restreindre la concurrence, en violation du premier paragraphe de l'article 101 du TFUE et de l'article L. 420-1 du code de commerce.

Figure A6: Parameter Identification



	κ	ρ	η	ξ	σ	ζ
Cartel overcharge	0.786	0.773	-0.537	-1.178	1.677	1.784
Aggregate markup	0.001	0.014	-0.013	-0.167	0.578	-0.020
Regression coefficient	0.000	0.000	2.273	0.000	0.000	0.000
Fr. firms rel. sales (0.1)	-0.076	5.738	0.692	-5.702	63.085	-0.023
Fr. firms rel. sales (0.5)	-0.026	0.496	0.149	-0.585	1.484	-0.005
Fr. firms rel. sales (1)	-0.011	0.152	0.061	-0.180	-0.196	0.010
Fr. firms rel. sales (2)	-0.006	0.014	0.034	-0.030	-0.111	0.092
Fr. firms rel. sales (5)	0.002	-0.015	0.003	0.004	-0.177	-0.007
Fr. firms rel. sales (10)	0.001	-0.016	0.000	0.013	-0.124	-0.014
Fr. firms rel. sales (50)	0.000	-0.002	-0.001	0.002	-0.019	-0.002
Fr. firms rel. sales (100)	0.000	-0.001	-0.000	0.002	-0.013	0.000
Fr. sales in firms rel. sales (0.1)	-0.133	3.431	0.332	-3.729	-53.632	1.802
Fr. sales in firms rel. sales (0.5)	0.041	-1.828	-0.188	1.867	-33.565	0.279
Fr. sales in firms rel. sales (1)	0.045	-1.996	-0.226	2.038	-26.839	0.162
Fr. sales in firms rel. sales (2)	0.047	-1.983	-0.250	2.019	-21.078	0.411
Fr. sales in firms rel. sales (5)	0.063	-1.714	-0.338	1.706	-15.070	-0.154
Fr. sales in firms rel. sales (10)	0.077	-1.348	-0.330	1.505	-10.398	0.104
Fr. sales in firms rel. sales (50)	0.002	-0.537	-0.253	0.688	-4.089	-0.241
Fr. sales in firms rel. sales (100)	-0.004	-0.314	-0.142	0.585	-2.910	0.185
Median nbr. firms	0.000	0.000	0.000	0.000	-1.266	0.000
Median nbr. cartel members	0.000	0.000	0.000	0.000	0.000	0.000

Notes: This figure shows the sensitivity of moments to parameters. The numbers are obtained by computing the elasticity of moments with respect to parameters —evaluated at the calibrated parameters.