CPRC Discussion Paper Series

Competition Policy Research Center

Japan Fair Trade Commission

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Masato Nishiwaki

Associate Professor, Graduate School of Economics, University of Osaka and

Visiting Researcher of the Competition Policy Research Center

CPDP-100-E February 2025

1-1-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8987 JAPAN

Phone: +81-3-3581-1848 Fax: +81-3-3581-1945

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July 9, 2024

Abstract

The concern that vertical integration facilitates collusion has been stated in merger guidelines of many jurisdictions. However, the effects of vertical integration on collusion have not been well understood and documented. This paper studies the relationship between vertical integration and upstream collusion by focusing on a cement cartel in Japan. A model of firms' behavior in vertically related markets is constructed and estimated. The counterfactual analysis shows that when vertical integration is eliminated altogether, the critical discount factor increases, meaning vertical integration facilitated collusion. It also shows that some hypothetical vertical mergers hinder collusion, highlighting the importance of merger characteristics.

JEL Classification: L41, L42
Keywords: Vertically Related Markets, Vertical Integration, Collusion, Successive Oligopolies

*Graduate School of Economics, University of Osaka. E-mail: m.nishiwaki@econ.osaka-u.ac.jp. I would like to thank Takanori Adachi, Noriaki Matsushima, Jun Nakabayashi, Hiroyuki Odagiri, and Tadashi Sekiguchi for their comments. I also benefited from the comments of conference and seminar participants at APIOC2022 (Sydney), the Applied Structural Econometrics Workshop (Singapore), EARIE2023 (Rome), the Japan Empirical IO Workshop (JEMIOW Osaka 2020), the Japan Fair Trade Commission, and Hitotsubashi and Kyoto universities. The research has benefitted from a financial support from the JSPS Grant-in-Aid for Scientific Research (C):No.T20K016060. All errors, of course, are mine.

1 Introduction

The identification of factors that facilitate or hinder collusion has been one of the primary research objectives in the field of industrial organization (IO). IO theorists have studied how different market structures, firm characteristics, and business practices influence firms' incentive to collude and demonstrated in what ways these factors affect collusive behavior. In addition, empirical researchers in the IO field have tested these theories and checked their applicability in different industries and markets using real-world data. The developments in the theoretical and empirical literature have helped researchers to better understand key factors influencing collusive conduct.[1]

Although understanding of pro- and anti-collusive market characteristics has been advancing, there are still factors that antitrust authorities are concerned about but that have not received sufficient attention in the academic literature. One of these concerning factors is the effects of vertical integration on collusion. The possibility that stronger vertical relationships between upstream and downstream firms facilitate collusive behavior has been a concern of antitrust agencies in many jurisdictions. For instance, in the Non-Horizontal Merger Guidelines, the Department of Justice (DOJ) in the U.S. expresses its concern on the coordinated effects that vertical integration can entail.[2] Similar concern can be found in the non-horizontal merger guidelines of the European Commission (EC), the Competition and Market Authority (CMA) in the United Kingdom, and the Japan Fair Trade Commission (JFTC).

Despite such concern in competition policy practice, academic researchers in the field of antitrust economics have mostly ignored the issue of coordinated effects.[3] In fact, the first

[1]Examples of factors facilitating collusion include smaller numbers of firms, higher concentration, product homogeneity, firm (cost) symmetry, demand stability, less buyer power, multi-market contacts, and cross-ownerships. See Motta (2004), Whinston (2006), and Marshall and Marx (2012) for detailed discussions.

[2]Coordinated effects refer to the effects of mergers with regard to potential increased coordination among firms, whether this be tacit or explicit (Marshall and Marx 2012)

[3]This seeming lack of interest by academic researchers in the coordinated effects of vertical integration stands in sharp contrast to the substantial interest that the coordinated effects of horizontal mergers have received.

theoretical study on the subject, by Nocke and White (2007), was published nearly a quarter century after antitrust authorities first expressed their concerns over the coordinated effects of vertical integration (in the DOJ's Non-Horizontal Merger Guidelines issued in 1984). The body of theoretical literature on the topic has recently started to increase, with the seminal work by Nocke and White (2007) being followed by studies by Normann (2009), Nocke and White (2010), and Biancini and Ettinger (2017). On the other hand, the empirical literature is lagging behind: little empirical work documenting the relationship between vertical integration and collusion has been conducted to date. This is a gap that needs to be filled.[4]

Against this background, the goal of the present paper is to empirically examine how vertical integration affects (upstream) firms' incentive to collude in vertically related markets. To this end, the present paper studies the cement cartel in the late 1980s in the Chugoku region, the westernmost region of Japan's main island. The cartel included nine cement firms that were operating in the region at that time. It was initiated in June 1985 and was terminated by the firms themselves when the JFTC started a cartel investigation in another region. (The cartel was uncovered later through the nationwide cartel investigation.) Important aspects of this cartel were that it consisted of upstream collusion in the vertically related cement and ready-mixed concrete markets and that (some of) the cement firms involved had integrated ready-mixed concrete firms. Therefore, the cement cartel provides a good case study to empirically examine the effects of vertical integration on upstream firms' incentive to collude.

To explore cement firms' incentive to collude, a structural model that incorporates the two main features – collusion by (upstream) cement firms and vertical integration between cement and ready-mixed concrete firms – is constructed and estimated. The first of these features, the collusive behavior of cement firms, can be modeled in a relatively simple way, taking

[4]In the latest volume of the Handbook of Industrial Organization, Asker and Nocke (2021, p.253) highlight that "empirical work on the link between vertical mergers and collusion is...largely absent from the modern literature. This strikes us as a gap that, while challenging to fill, may have considerable benefits in providing a set of mappings from theory to observed phenomena and magnitudes of impact."

advantage of the facts made public by the cartel investigation.[5] For modeling purposes, the most important aspect is that the cartel jointly controlled the total amount of supply in the region and each cement firm's supply was constrained by the quotas agreed. Given this, colluding cement firms are modeled to be capacity-constrained. The shadow prices associated with their quotas (indirectly) measure the extent to which the cement firms reduced their supply during the period the cartel existed.

Second, to deal with the vertical relationship between cement and ready-mixed concrete firms, the theoretical model builds upon the framework of successive oligopolies (Greenhut and Ohta 1979; Salinger 1988; Gaudet and Van Long 1996). One characteristic of the cement and concrete markets is that both vertically integrated and unintegrated firms coexist. Unintegrated cement firms supply cement to local markets, which consist mainly of unintegrated concrete firms, while integrated cement firms supply to their own concrete firms internally and to unintegrated concrete firms in the external market. Therefore, vertically integrated cement firms need to balance the profits gained from their integrated concrete firms and those obtained by selling cement to unintegrated firms in the external market. This nature of the profit maximizing behavior of vertically integrated (and unintegrated) cement firms is taken into account in the theoretical model.

The main objects of the estimation are the (upstream and downstream) firms' marginal costs and shadow marginal costs. However, it is difficult to estimate these two types of marginal costs separately. To address this issue, the antitrust penalty imposed on the cement industry by the JFTC will be utilized. Specifically, after they were convicted in December, 1990, the colluding cement firms were required to report their sales activities to the JFTC for three years as part of the antitrust penalties. The monitoring by the JFTC of these firms makes it possible to estimate their marginal costs and shadow prices separately, because firm conduct in this period can be regarded as competitive.[6]

[5] The documents are available on the JFTC's website.

[6] The approach of using two different competitive regimes to estimate the marginal cost functions and the effects of collusion is often used in empirical studies of collusion (e.g., Porter 1983; Ellison 1994; Igami 2015).

Using estimates of the demand and cost parameters, counterfactual analyses are conducted to quantify cement firms' incentive to collude. Specifically, how vertical integration affects firms' incentive to collude is examined by quantifying differences in the critical discount factor under the actual and counterfactual market structures. The first result is that when the actual vertical integration is eliminated altogether, the critical discount factor becomes higher, meaning that vertical integration as a whole facilitated collusion among the cement firms. The main reason is that the deviation profit of each cement firm is reduced by the vertical integration of other firms and, as a result, firms have less incentive to deviate under the actual market structure.

The second, more interesting, result comes from the counterfactual analysis of additional hypothetical vertical mergers. The analysis aims at exploring whether vertical mergers by different firms have different impacts on collusion. For every cement firm, the hypothetical scenario where the firm merges with a concrete firm that is not actually integrated is examined to see whether a vertical merger by that firm would facilitate or hinder collusion. One of the striking results is that, when the cement firm with the highest critical discount factor under the actual market structure merges with a concrete firm, the critical discount factor increases, meaning that this merger makes upstream collusion difficult. In contrast, when firms with a relatively low critical discount factor merge with the same concrete firm, these vertical mergers have no impact on collusion.

The set of these results provides an important insight into competition policy with regard to the coordinated effects of vertical integration. That is, whether a vertical merger facilitates or hinders collusion depends on what kind of upstream firm is involved in the merger, meaning that merger characteristics matter for the evaluation of the impacts of a vertical merger on collusion. At the same time, these implications echo those obtained in the literature on the coordinated effects of horizontal mergers. Studies have highlighted that, in settings with heterogeneous firms, different horizontal mergers can have different effects on collusion and a horizontal merger may facilitate or hinder collusion, depending on the merger characteristics

(Compte, Jenny, and Rey 2002; Vasconcelos 2005; Igami and Sugaya 2022). The present paper complements the existing work on the coordinated effects of mergers by highlighting the role of firm heterogeneity in vertically related markets.

The novelties of the present paper can be summarized as follows. First and foremost, this paper is one of the first empirical studies of collusion in vertically related markets. Focusing on a criminal cartel in the cement industry in Japan, the relationship between vertical integration and upstream collusion is empirically examined employing a structural model. Second, and closely related to the first point, the present paper analyzes the coordinated effects of mergers from a new angle, by focusing on vertical integration, and provides the new finding that the effects of vertical mergers depend on merger characteristics. Third, the present study is one of only a handful of empirical studies using the framework of successive oligopolies. Although there have been many theoretical models built on this framework, little empirical work utilizing it has been conducted (exceptions are Villas-Boas 2007, 2009; Mortimer 2008; Bonnet and Dubois 2010; Asker 2016).[7] The present paper provides a good example of how the model of successive oligopolies can play an important role in empirical work.

The rest of the paper is organized as follows. The next section provides a review of the related literature, followed by an outline in Section 3 of the cement cartel in the Chugoku region of Japan. Section 4 then provides a description of the cement and ready-mixed concrete industries, while Section 5 introduces the data used in the analysis. Next, Section 6 develops the model describing cement firms' collusive behavior during the cartel period, while the estimation of the model is presented in Sections 7 and 8. Finally, Section 9 presents the counterfactual exercises examining the effects of vertical integration on cement firms' incentive to collude. Section 10 concludes.

[7] On the other hand, there is a rapidly growing empirical literature using bargaining models (Lee, Whinston, and Yurukoglu 2021).

2 Related Literature

The present paper is based on the ideas developed in the theoretical literature on vertical integration and collusion. The seminal theoretical work on the relationship between vertical integration and (upstream) collusion is the study by Nocke and White (2007). They study how a vertical merger affects the incentive to collude for upstream firms. In their simplest setup, one upstream firm vertically integrates one downstream firm. This vertical merger has two types of counteracting effects on collusion. On the one hand, the vertical merger allows the integrated upstream firm to obtain positive profits even in the punishment phase (if downstream competition is not characterized by perfect competition). Therefore, the firm's incentive to deviate increases with the vertical merger. This effect of vertical integration on the integrated upstream firm is called the punishment effect.

On the other hand, the vertical merger has an effect on unintegrated upstream firms in the opposite direction. After the vertical merger, unintegrated upstream firms no longer sell to the integrated downstream firm, leading to a reduction in their deviation profits. This effect is called the outlets effect. Additionally, the integrated upstream firm can start retaliation at the downstream stage immediately after it detects a deviation by any other firm at the upstream stage. Therefore, the deviation profits of unintegrated upstream firms are further reduced. This effect is called the reaction effect. These effects reduce unintegrated firms' incentive to deviate.[8] Nocke and White (2007) show that the net result of these counteracting effects is to facilitate upstream collusion.

Normann (2009) studies the effects of vertical integration in a different setting in which upstream firms use linear prices, instead of two-part tariffs as in Nocke and White (2007). Normann identifies the punishment effect on an integrated upstream firm and the outlets and reaction effects on unintegrated upstream firms and confirms that vertical integration facilitates upstream collusion by reducing the critical discount factor.

[8]Nocke and White (2007) identify another effect, which they called the lack-of-commitment effect. However, this effect is less relevant to the present paper.

Apart from the theoretical literature on vertical mergers, the present paper is related to the empirical literature on collusion and mergers. The most relevant studies in this field are structural analyses. One example is the study by Igami and Sugaya (2022), who explore the causes leading to the collapse of the vitamin C cartel. In addition to analyzing cartel stability, they also quantify the coordinated effects of a (hypothetical) horizontal merger. Another closely related study is that by Miller and Weinberg (2017), who examine the possible price effects caused by the MillerCoors joint venture by estimating parameters that represent the departure from Bertrand-Nash pricing and document possible price coordination between the companies involved in the joint venture. The difference between these studies and the present study is that this study focuses on vertically related markets.

A study that examines explicit collusion is that that by Clark and Houde (2013), who examine the mechanism that enables heterogeneous gasoline retailers in the US to collude. Using court documents, they infer the marginal costs and quantify the effects of the transfer mechanism employed in the gasoline cartel. The present paper shares the basic idea of estimating marginal costs using legal documents revealed in the prosecution process, although the interest of the present paper is in exploring the relationship between collusion and vertical integration not in examining the mechanism that the cartel used.

Another related strand of research is the literature on vertical integration and restraints. Examples of studies conducting structural analyses of vertical integration include those by Houde (2012), Lee (2013), Asker (2016), Crawford, Lee, Whinston, and Yulukoglu (2018), and Luco and Marshall (2020), while recent non-structural analyses of the unilateral effects of vertical integration include those by Chipty (2001), Hastings (2004), Hastings and Gilbert (2005), Hortaçsu and Syverson (2007), and Suzuki (2009). The present paper complements the current empirical research by focusing on the coordinated effects of vertical integration.

3 The Cartel in the Chugoku Region

During the 1970s and 1980s, cement firms were convicted of involvement in cartels multiple times in different regions. Among these convicted cartels, the cartels in the Chugoku and Hokkaido regions, which were initiated in the summer of 1985 and uncovered in mid-1990, are among the most prominent cases in Japanese antitrust history. These two cartels were the largest cartels in Japan at the time of the conviction in terms of the fines involved. Moreover, the sum of the fines levied on the cement firms involved remained the largest for criminal cartels for over 15 years, until 2005.

This study examines the role of vertical integration in firms' incentive to collude by focusing on the cartel in the Chugoku region.[9] The nine cement firms were Aso Cement, Mitsubishi Cement, Mitsui Mining, Nihon Cement, Nippon Steel Chemical, Onoda Cement, Sumitomo Cement, Tokuyama, and Ube Industries (hereafter, the following short forms are used for these firms: Aso, Mitsubishi, Mitsui, Nippon Steel Chem., Onoda, Sumitomo, and Ube).[10] All of the nine cement firms were involved in the cartel, which was initiated in July 1985. The cartel lasted almost five years and ended in the middle of April in 1990. The cartel was not detected while the firms were actually colluding. In fact, the cement firms stopped colluding immediately after they realized that the JFTC had started cartel investigations into the firms in the Hokkaido region. However, the cartel was eventually uncovered, because the JFTC extended their investigation into all cement markets in Japan. Because all of the nine firms admitted their involvement in the cartel after it was discovered, the cartel case came to a quick conclusion in December 1990.

The JFTC documents reveal the workings of the cartel. A group of branch managers of the cement firms in the region organized the cartel. Two months before the cartel started,

[9] The main reason this study focuses on the cartel in the Chugoku region is data limitations. Because of its geographical size, it is difficult to regard Hokkaido as a single cement market, and important information, such as firm-level quantities, unfortunately is available at best at the prefecture level and not at a more detailed local level.

[10] Because it did not have its own supply network (it only started to build its own distribution centers in the late 1980s), Mitsui relied on Onoda's distribution network and cannot really be regarded as an independent firm. Therefore, in the analysis, Mitsui is treated as having merged with Onoda.

the branch managers agreed on how they were going to organize the cartel, including how to implement price increases and control supply quantities, how to allocate quotas, how to monitor cartel compliance, and how to establish mechanisms to avoid unintentional deviations.

During the cartel, the branch managers controlled the total amount of cement supply in the region to elevate prices. They met monthly to decide on the total amount of cement to supply and allocate quotas to the cement firms. The cartel's allocation rule was essentially based on the pre-cartel market shares, although there were (small) adjustments for some firms.[11] Table 1 presents the market shares before, during, and after the cartel. The firms' market shares remained almost unchanged across these different periods. Therefore, it is evident that the cartel intended to maintain the pre-cartel market shares.[12]

Finally, it is worth noting that the firms used some means to avoid a collapse of the cartel through unintended deviations from the cartel agreements. If a firm foresaw that its supply would exceed the quota, the sales manager would report this in advance and the firm would buy cement from another one of the firms at a non-market price to supply the extra amount. Alternatively, the quota for the next month would be reduced by that amount. Using these quantity-setting, allocation, and enforcement structures, the cement firms in the Chugoku region colluded for almost five years.

[11] For instance, Nippon Steel Chem. was allocated 4,300 tons (monthly) in addition to the share-based allocation, whereas 1,700, 1,500, and 1,000 tons were subtracted from the share-based amounts of Onoda, Ube, and Mitsubishi, respectively.

[12] Sales managers played a role in enforcing the cartel agreements. They met multiple times within a month and reported sales figures to each other. Unfortunately, details of how they monitored each other and how they verified these reports were not revealed. However, it can be inferred from a previous criminal cartel in the same region. Trucks used for cement delivery are specialized for this purpose, making it easy to monitor how much cement is delivered from a specific location. In the previous cartel, cement firms simply monitored the distribution centers of other firms to ensure compliance with the allocations. Therefore, while the enforcement structure of the cartel examined here was not revealed, it is likely that it followed a similar pattern.

4 The Vertically Related Markets

This section describes the cement industry in the Chugoku region and the main downstream industry, the ready-mixed concrete industry, and the vertical relationships between these two.[13]

4.1 Upstream: The Cement Industry

The Japanese cement industry is broadly divided into 11 different regions. Among these regions, the focus of this paper is the Chugoku region, which is the 9th largest market and accounts for around 8% of cement consumption in Japan. In this region, nine cement firms were present during the 1980s and the number remained the same until industry consolidation through horizontal mergers started in 1994.

Table 2 presents the firms' market shares and other characteristics (as of 1985). There is substantial heterogeneity in firm size. The three largest firms account for more than half of the market supply and the largest firm, Onoda, is five times larger than the smallest, Nippon Steel Chem. This heterogeneity stems mainly from differences in the size of their distribution networks, which can be gauged by the number of distribution centers or "service stations," and there is a strong link between a firm's number of service stations and its delivery costs.[14] As can be seen in Table 2, the pattern in firms' number of service stations closely follows that in their market shares. In fact, the correlation between firms' regional supply and their number of service stations is about 0.9, suggesting that the size of the distribution network is an important variable in cement supply.

[13]The cement and ready-mixed concrete industries are frequently used for empirical work in other countries as well (see, e.g., Jans and Rosenbaum 1996; Steen and Sorgard 1999; Syverson 2004; Röller and Steen 2006; Hortaçsu and Syverson 2007; Salvo 2010 Ryan 2012; Collard-Wexler 2013; Nishiwaki 2016; Backus 2020).

[14]Service stations play a key role in the cement supply chain. They are places to which cement is first delivered once it is produced at plants. Cement firms deliver their product using trucks from service stations to local customers. This transportation cost is relatively high. Therefore, cement firms have service stations within a region (or even a single prefecture) to reduce costly long-haul deliveries. Cement firms also deliver their product to customers' construction sites, in addition to customers' concrete plants. This means that they face uncertainty with regard to the distance from their service stations to construction sites. Because of this, it can be advantageous for firms to have several service stations in a regional market.

Table 2 also shows whether firms have cement producing plants in the region. Only three firms do so.[15] Other firms ship cement to the Chugoku region from their plants located in other regions. Shipping cement to (service stations in) a different region is possible and common in Japan because of relatively low transportation costs by sea.[16] Productivity at the production stage is related to the number of service stations.[17] There is a positive link between plant productivity and the number of service stations, so that cement firms that had more productive plants tended to supply more. The Chugoku region is a relatively small cement market, as indicated in the column labeled "Region/Total." This column shows the share that the Chugoku region accounted for in firms' total national supply. As can be seen, the region at most accounted for 22% of a firm's total national supply, while for many it was less than 10%.

Another important aspect of the cement and concrete industries is that cement firms have vertical relationships with concrete firms, as is also shown in Table 2. 94 out of 465 concrete firms in the region in 1985 were vertically linked to cement firms.A feature of vertical integration between cement and concrete firms is that integration is not necessarily 100%.[18] Out of the 94 vertically integrated concrete firms, only 20 firms were 100% owned by cement firms. In addition, only 34 were 50% or more owned by cement firms.[19]

[15] Onoda had two plants. However, the plant located in Yamaguchi prefecture was very small and accounted for only around 1.5% of Onoda's total production. Therefore, the other plant eventually produced almost all the cement supplied to the region.

[16] However, delivering cement from a service station to local customers is costly and competition in the Japanese cement industry is still localized, as is competition in the cement industry in many other countries.

[17] Productivity in Table 2 refers to the labor productivity of cement producing plants from which cement firms ship cement to the Chugoku region. If a cement firm uses more than one plant to supply the region, the share-weighted average of the labor productivity is used. While the analysis below uses labor productivity, total factor productivity could be used instead. However, the most important factor in cement production is the number of cement kilns that a firm uses because labor cannot substitute for capital in most parts of the production process. Therefore, once capital equipment is installed, the amount of labor is mechanically determined.

[18] Whether or not partial integration between cement and concrete firms is common in other countries is not clear from other empirical studies. For instance, in Syverson and Hortaçsu (2007), all vertically integrated concrete plants in the U.S. are treated equally as vertically integrated plants.

[19] Regarding the timing of when cement firms invested in concrete firms, in most cases this occurred when concrete firms were established, since the ownership of ready-mixed concrete firms does not change frequently. Historically, cement firms invested in ready-mixed concrete firms in the 1950s and 1960s to secure sales outlets. In the 1970s, this expansion process slowed down. As a result, the number of integrated concrete firms remained almost unchanged in the 1980s and early 1990s, although the ratio of integrated

Cement Markets in the Chugoku Region The Chugoku region consists of five different prefectures: Hiroshima, Okayama, Shimane, Tottori, and Yamaguchi. One way to define local cement markets in this region is to treat each prefecture as a local market. However, in this study, Shimane and Tottori prefectures are regarded as one market, for the following reasons. First, these prefectures are relatively small. Their combined population is comparable to that of Yamaguchi, the third largest prefecture in the region. Second, and more importantly, cement prices in these prefectures are essentially identical, suggesting that they cannot really be regarded individual cement markets. Thus, this study considers four cement markets: Shimane-Tottori, Hiroshima, Okayama, and Yamaguchi.

4.2 Main Downstream Industry: The Ready-Mixed Concrete Industry

The ready-mixed concrete industry is the largest downstream industry for cement producers. The industry accounts for over 80% of total cement consumption.[20] The ready-mixed concrete industry consists of a large number of small firms. The total number of ready-mixed concrete firms in the Chugoku region in 1985 was 465.[21] Moreover, the vast majority of ready-mixed concrete firms are single-plant firms and the average number of plants per firm is about 1.2.

Table 3 provides an overview of the ready-mixed concrete industry in the Chugoku region as of 1985. There were 465 concrete firms, of which 94 firms were vertically integrated with cement firms. However, among these integrated firms, only 34 firms were more than 50% owned by a cement firm, as mentioned earlier. Comparing vertically integrated and vertically unintegrated firms in terms of their size based on the capital used in production shows that the former are about 1.7 times as large as the latter. Therefore, although the number of

to unintegrated concrete firms changes over time as a result of the entry and exit of unintegrated concrete firms.

[20]The second largest industry is the cement- and concrete-related products industry, which accounts for around 10% of total cement consumption.

[21]The definition of a concrete firm is provided in the Online Appendix.

vertically integrated concrete firms is not very large, they play a large role in the concrete industry.

Local Concrete Markets Competition in the ready-mixed concrete industry is more localized than that in the cement industry due to the high transportation costs.[22] Even a single prefecture comprises several local ready-mixed concrete markets, and defining local ready-mixed concrete markets as accurately as possible is important to capture the behavior of concrete firms. To define local cement markets, the present study uses a price survey by a governmental research organization, the Construction Research Institute (Kensetsu Bukka Chosa-Kai in Japanese). This research institute was founded in 1955 under the aegis of the Ministry of Land (currently, the Ministry of Land, Infrastructure, Transport and Tourism, MLIT), and its main activity is to survey the prices of almost all materials and services used in construction.[23]

For the ready-mixed concrete industry, the institute surveys prices in geographically distinct cities and towns to determine how ready-mixed concrete prices differ from one area to another. The present study utilizes these cities and towns selected by the institute to define local concrete markets. Because the institute's main objective is to examine variations and trends in the prices of materials used in construction, it is natural to assume that the institute selects cities and towns to represent local concrete markets.[24] Based on this assumption, a ready-mixed concrete market here is defined as a city or town representing a particular local market and its surrounding cities and towns. Specifically, each city or town in a prefecture is matched to the nearest representative city or town for which concrete prices are surveyed.[25]

[22] In other countries such as the U.S. and European countries, high delivery costs are the main reason for competition being localized. In Japan, there is another reason: ready-mixed concrete producers need to finish the delivery within 1.5 hours. This is one of the requirements in the Japan Industrial Standards (JIS), which plays a role in the de facto regulation of the quality of industrial products. The requirements that concrete firms need to satisfy in order to be certified are stipulated in JIS-A5308.

[23] These prices are made public in their monthly magazine, called Kensetsu Bukka.

[24] When defining local concrete markets in this manner, an issue that arises is that the institute expanded its survey during the 1980s and, as a result, the number of cities and towns surveyed has increased. Against this background, the present study uses 21 cities and towns that appeared in the price survey in April 1991, since no cities and towns were added in the remainder of the 1990s.

[25] All cities and towns are no more than 20km as the crow flies from at least one city or town in the survey.

A local concrete market is defined as a survey city or town and the cities and towns matched to the survey city or town.

A typical local concrete market contains about 16 firms and around three firms are vertically integrated.

5 Data

The data used in the present study are collected from multiple sources. The primary data source is the Cement Industry Yearbook. The yearbook provides data on the total cement consumption in each prefecture and the consumption of downstream sectors. In addition, it provides data on cement firms' (annual) supply quantity in each prefecture. Further, apart from quantity, it also provides other information on cement distribution centers and producing plants, such as location, production quantity, the number of workers, the scale of capital equipment, and capacity. Moreover, the yearbook lists the firms with which each cement firm has a capital relationship, making it possible to determine which cement firm owns which concrete firms. An important limitation of the yearbook is that it lacks prefecture-level price information. Therefore, cement prices at the prefecture level are obtained from a magazine published by the Construction Research Institute that provides the prices of almost all (raw) materials used in construction.[26]

Information on the main downstream industry, the ready-mixed concrete industry, is obtained primarily from the Ready-Mixed Concrete Industry Yearbook. The contents of this yearbook are similar to those of the Cement Industry Yearbook. This yearbook provides yearly firm- and plant-level information, including the locations of the headquarter offices and producing plants, the scale of capital equipment, and the number of workers. In addition to these firm- and plant-level characteristics, information on the ownership structures of concrete firms is provided. This information makes it possible to establish not only whether a

[26] Although monthly cement prices are available, the annual average of these monthly prices is used in this study. The reason is that other important information, such as firm-level supply quantities and firm characteristics including the number of service stations, are typically available only annually.

concrete firm is vertically integrated with a cement firm but also the cement firm's ownership share in the concrete firm.

Although the Ready-Mixed Concrete Industry Yearbook is a valuable information source, it has two limitations. First, it does not contain firm- (and plant-) level supply quantities. Due to this limitation (and the absence of any other sources), it is necessary to estimate the supply quantities of individual concrete firms. The estimation is based on the scale of capital equipment that each concrete firm uses, which is closely related to the production capacity of the firm. Each concrete firm's capacity share in the prefecture is calculated. This capacity share is then multiplied by the total amount of supply to obtain a proxy for each concrete firm's supply quantity.

The second limitation of the Ready-Mixed Concrete Industry Yearbook is that although it contains prefecture-level price information, it does not provide price information at the market level. To deal with this limitation, the Census of Manufactures (by the Ministry of Economy, Trade, and Industry) is utilized to obtain prices in local ready-mixed concrete markets.[27] For each local concrete market, the average price is calculated using the revenue and supply quantities of plants ('establishments' in the terminology of the Census) in the local market.[28]

The prices of gasoline, coal, and fuel oil (No.6) are also collected. The prefecture-level prices of gasoline, which cement and ready-mixed concrete firms use in the delivery stages of their product, are obtained from the Retail Price Survey released by the Statistics Bureau, the Ministry of Internal Affairs and Communications. The prices of coal, which is used in the cement production process, and of fuel oil, which is used in shipping cement by sea from

[27]The magazine by the Construction Research Institute that is used for collecting cement prices could be used for collecting concrete prices. However, the number of cities and towns surveyed by the institute increased in the 1980s. This means that for cities added to the survey after 1985, the prices before that year are not available.

[28]The Census of Manufactures surveys plant-level information on sales, the number of employees, the total wages paid to them, the amount of capital, and the amount of raw materials and energy used. However, the Census does not provide the names and addresses of plants, meaning that it is not possible to merge information from the Census and the Ready-Mixed Concrete Industry Yearbook. Therefore, the Census is used only for calculating local concrete prices.

cement producing plants to local markets, are obtained from the Energy Information Center. The prices of these two fuels do not vary across prefectures in the Chugoku region and are only time-variant.[29]

The number of construction workers, which in the analysis is used as the main demand shifter (for both concrete and cement), is obtained from the Population Census published by the Statistics Bureau.[30] However, the survey is conducted only every five years. This means that during the period on which this study focuses, the only years when the Population Census was conducted are 1985 and 1990. Therefore, for other years, the number of construction workers in each city is extrapolated.[31] The amount of construction investment, which is provided by MLIT, is also used as a demand shifter for the cement industry.

Table 4 provides descriptive statistics of the data. Since important information, such as prefecture- and firm-prefecture-level cement supply, is only available on a yearly basis, for other variables that are available on a monthly basis, annual averages are used. In addition, variables available on a yearly basis are divided by 12 to convert them to monthly variables. The reason for changing these annual variables to monthly variables is that the cartel determined the total regional supply on a monthly basis and cement firms acted according to their monthly quotas. The model introduced below describes this behavior of cement firms. To match the time-period of the data to the timeframe for firms' decision making in the model, the prefecture and prefecture-firm supply quantities need to be defined as monthly variables. Consequently, cement firms' behavior within a typical month of a given year is described in the model.[32]

[29] Monthly gasoline, coal, and fuel oil prices are available. However, as noted previously, important variables are available only on an annual basis, so that the annual average prices of them are used.

[30] The number of construction workers has been widely used in previous studies to define the size of the concrete market (Syverson 2004; Collard-Wexler 2013; Backus 2020).

[31] Details are provided in the Online Appendix.

[32] Therefore, subscript t in the model represents a typical month of year t.

6 Model

This section presents a theoretical model describing firms' behavior in the cement and ready-mixed concrete markets. The model is based on the framework of successive oligopolies with vertical integration. One feature of the cement and ready-mixed concrete markets is that vertically integrated cement firms supply their product to both their own and unintegrated downstream firms. This situation is a clear contrast to standard models where, once an upstream firm and a downstream firm are integrated, the vertically integrated upstream firm becomes the exclusive input supplier to the integrated downstream firm (Greenhut and Ohta 1979; Salinger 1988). On the other hand, Gaudet and Van Long (1996) develop a model that can handle situations where vertically integrated upstream firms are allowed to supply inputs to independent downstream firms as well as their downstream firms. Because of this flexibility, their model is suitable to explain the cement and ready-mixed concrete markets.[33]

Another feature of the cement and ready-mixed concrete markets is upstream collusion. In general, describing collusive behavior is challenging. For the present study, fortunately, the findings of the JFTC investigation are available to model the cement firm cartel. Based on these findings, firms in this study are described as capacity-constrained firms during the cartel period. As a result, the effects of the cartel appear in the form of shadow prices.[34]

6.1 Cement Firms and Collusion

This subsection introduces the strategy for modeling cement firms' behavior during collusion, leaving the details of the successive oligopoly model to the following subsections. As

[33]The model developed by Gaudet and Van Long (1996) is even more flexible. It allows a vertically integrated downstream firm to purchase inputs from both integrated upstream firm and other (unintegrated) upstream firms. However, this aspect of their model is not relevant to the present study, because vertically integrated concrete firms only obtain supplies from their parent firm.

[34]This approach to modeling colluding firms is similar to the approach employed in Goldberg (1995) and Berry, Levinsohn, and Pakes (1999) in modeling the export restrictions on Japanese car makers due to voluntary export restraints (VERs) in the 1980s and 1990s. The VERs act as capacity constraints and the effects appear as shadow prices.

mentioned, the information revealed by the JFTC's cartel investigation is exploited to model the collusive behavior. In particular, the following factors regarding the cartel allocation rule are important.

The cartel's primary objective was to control the total amount of cement supply in the region to raise cement prices. To limit the total amount of cement supply, cement firms were allocated (monthly) quotas based on the allocation rule that the cartel had agreed on. Because the cartel did not collapse, it is assumed that firms adhered to their allocated quotas. As a result, the quotas worked as strict capacity constraints beyond which cement firms could not supply.

Another aspect is that while the total amount of cement that a firm could supply within the region was restricted by the cartel allocation rule, the amount it could supply to individual prefectures within the region was not. Put differently, as long as firms adhered to their allotted quotas, they were free to determine their supply quantities to prefectures in the region.

Given these facts, it is reasonable to assume that, once the total supply is set by the cartel and the quotas are then determined based on the allocation rule, a cement firm's objective is to maximize its profit by choosing the quantities that it supplies to prefectures, given that other cement firms comply with their quotas and maximize their profits in the same way. Formally, cement firm i's profit maximization problem under collusion is given by the following constrained optimization problem:

$$\max_{\boldsymbol{q}_{it}^{nv}, \boldsymbol{q}_{it}^{v}} \sum_{p=1}^{P} \Pi_{ipt}(q_{ipt}^{v}, q_{ipt}^{nv}) \qquad s.t. \;\; \bar{Q}_t \overline{\sigma}_{it} \geq \sum_{p=1}^{P} \left(q_{ipt}^{nv} + q_{ipt}^{v} \right) \qquad i = 1, \ldots, N^U \tag{1}$$

where $\boldsymbol{q}_{it}^{nv} \equiv \{q_{ipt}^{nv}\}_{p=1}^{P}$ and $\boldsymbol{q}_{it}^{v} \equiv \{q_{ipt}^{v}\}_{p=1}^{P}$. $\Pi_{ipt}(q_{ipt}^{v}, q_{ipt}^{nv})$ is the profit of firm i in period t.[35] q_{ipt}^{nv} is the quantity supplied to unintegrated concrete firms in cement market p, while q_{ipt}^{v} is the quantity supplied to firm i's ready-mixed concrete firms. $\bar{Q}_t \overline{\sigma}_{it}$ denotes the quota

[35] As explained in the data section, cement firms' behavior within a typical month of a given year is described in the model.

allocated to firm i, where $\bar{Q}_t$ is the total regional supply set by the cartel and $\overline{\sigma}_{it}$ is the share allocated to firm i. Only the firm's total supply in the region is subject to the quota constraint and the constraint is assumed to be binding. N^U is the number of cement firms, which is eight, and P is the number of cement markets (prefectures), which is four.

At this point, it is worth noting that the cartel's decision on $\bar{Q}_t$ is abstracted away from the model. The model focuses on individual cement firms' behavior after the cartel's decision is made. This modeling strategy greatly simplifies the analysis. In addition, describing individual firms' decisions on q^{nv}_{ipt} and q^{v}_{ipt} is sufficient to recover parameters in the marginal cost function of the cement firms (see Section 7). However, one potential drawback of abstracting away from the cartel's decision on $\bar{Q}_t$ is that the cartel's decision on total output in a counterfactual cannot be predicted. Therefore, in the subsequent analyses, it is necessary to consider an alternative way to obtain $\bar{Q}_t$ for counterfactual situations.

6.2 Cement Firms' Profits

Cement firm i's profit in prefecture p consists of three types of profit: the profit obtained from the prefectural cement market, the profit generated internally from its vertically integrated concrete firms (if cement firm i has vertically integrated concrete firms), and the sum of the profits of the vertically integrated concrete firms. That is, the (monthly) profit of cement firm i in prefecture p is defined as follows:[36]

$$\Pi_{ip} = \underbrace{\sum_{m=1}^{M_p}\sum_{d^i=1}^{N^D_{imp}} \varsigma_{d^i mp}\pi^D_{d^i mp}}_{\text{Profit from downstream firms}} + \underbrace{\sum_{m=1}^{M_p}\sum_{d^i=1}^{N^D_{imp}} (W_{d^i mp} - c^U_{ip}) q^v_{d^i mp}}_{\text{Profit from supplying integrated firms}} + \underbrace{(W_p - c^U_{ip}) q^{nv}_{ip}}_{\text{Profit from supplying the market}}. \quad (2)$$

The first term is the sum of the profits of firm i's ready-mixed concrete firms. $\pi^D_{d^i mp}$ denotes the profit of concrete firm d^i, which operates in local concrete market m in p, and $\varsigma_{d^i mp}$ denotes cement firm i's ownership share in firm d^i. N^D_{imp} is the number of integrated concrete

[36] In the remainder of this section, subscript t denoting time will be dropped for ease of notation.

firms owned by firm i and M_p is the number of concrete markets in p. The second term denotes the sum of the profits obtained by selling cement to vertically integrated concrete firms. W_{d^imp} denotes the cement price at which firm d^i is supplied by firm i internally, and $q^v_{d^imp}$ denotes the amount of cement that is supplied to firm d^i. The last component is the profit obtained by selling cement to the prefectural cement market, where the main buyers are vertically unintegrated concrete firms.[37] W_p is the cement market price and q^{nv}_{ip} is firm i's market supply. c^U_{ip} is the marginal cost of firm i and is assumed to be invariant across concrete markets in p.

Cement firm i's constrained profit maximization problem is expressed as the following Lagrangian:

$$L(\boldsymbol{q}^v_i, \boldsymbol{q}^{nv}_i, \lambda_i) = \sum_{p=1}^{P} \left\{ \sum_{m=1}^{M_p} \sum_{d^i=1}^{N^D_{imp}} \left\{ \varsigma_{d^imp} \pi^D_{d^imp} + (W_{d^imp} - c^{U,\lambda}_{ip}) q^v_{d^imp} \right\} + (W_p - c^{U,\lambda}_{ip}) q^{nv}_{ip} \right\} + \lambda_i \bar{Q} \overline{\sigma}_i \quad (3)$$

where λ_i represents the shadow marginal cost of firm i and $c^{U,\lambda}_{ip}$ is the sum of the actual and shadow marginal costs, $c^{U,\lambda}_{ip} = c^U_{ip} + \lambda_i$. The shadow marginal cost effectively increases firm i's marginal cost and thus reduces its supply.[38]

$\pi^D_{d^imp}$ depends on the market price of cement (as well as internal cement prices). The reason is that the market price of cement influences unintegrated concrete firms' marginal costs and, as the result of interactions between vertically integrated and unintegrated concrete firms, the cement market prices influences $\pi^D_{d^imp}$.[39] In the next subsection, concrete firms' profit function is defined.

[37]Firms in other downstream sectors also purchase cement, as will be explained later.

[38]An alternative specification would be that the concrete firms owned by firm i are directly constrained by the upstream firm's quota. In this case, λ_i is added to the downstream firm's marginal cost. The supplies of less-than-100%-owned concrete firms are slightly more restricted than in the specification in the main text. Consequently, the market supply q^{nv}_{ip} increases. However, this does not change the final results and conclusions of the analysis in this study.

[39]As explained in the next subsection, the possibility that vertically integrated concrete firms' input prices are affected by market price W_p is also considered.

6.3 Ready-Mixed Concrete Firms' Profits

The ready-mixed concrete market is more localized than the cement market and a prefecture comprises several local concrete markets. There are two types of concrete firms, vertically integrated and unintegrated firms. The main difference between them is that vertically integrated firms purchase cement from their cement firms at cement price $W_{d^i mp}$, whereas unintegrated concrete firms purchase cement at market price W_p in the prefectural cement market.

Vertically Integrated Concrete Firms A ready-mixed concrete firm owned by cement firm i is denoted by d^i.[40] The profit function of firm d^i in local concrete market m in prefecture p is given by the following:

$$\pi^D_{d^i mp} = (P_{mp} - c^D_{d^i mp})s_{d^i mp} = (P_{mp} - \tilde{c}^D_{d^i mp} - \tau W_{d^i mp})s_{d^i mp} \tag{4}$$

where P_{mp} is the price of ready-mixed concrete in market m in p and $c^D_{d^i mp}$ is the marginal cost of firm d^i. $s_{d^i mp}$ is the quantity supplied by firm d^i. $\tilde{c}^D_{d^i mp}$ represents marginal costs other than the cost of cement, such as the cost of water, gravel, and sand, as well as other costs incurred in the concrete production and delivery stages. τ denotes the cement-concrete ratio assumed in the analysis. The cement-concrete ratio refers to the ratio of cement to aggregates in a concrete mixture. Here, a fixed-proportions technology is assumed, and the ratio is fixed at 0.3 throughout this study.[41] $W_{d^i mp}$ represents the cement price at which firm d^i is internally supplied by cement firm i.

In contrast to the typical situation studied in the theoretical literature on vertical integration, one feature of the vertical relationships between cement and concrete firms is that the majority of vertically integrated concrete firms are not fully but partially owned by

[40] There are no concrete firms that are owned by multiple cement firms.

[41] Other empirical studies on cement and concrete markets also assume that ready-mixed concrete production is a fixed-proportions technology, such as Hortaçsu and Syverson (2007). In the case of the Japanese ready-mixed concrete industry, as explained earlier, the cement-concrete ratio needs to meet the criteria of the JIS.

cement firms. Another issue is that no information is available on internal cement prices. If such information were available, it would be possible to empirically check how internal cement prices vary with cement firms' ownership shares. Unfortunately, such information is not available. Consequently, it is necessary to make assumptions about how internal cement prices are determined.[42]

The first assumption is that $W_{d^i mp}$ is related to cement firm i's ownership share in concrete firm d^i, $\varsigma_{d^i mp}$. The second assumption is that $W_{d^i mp}$ falls in a range of $c_{ip}^{U,\lambda}$ (or c_{ip}^{U}) to W_p. Formally, $W_{d^i mp}$ is expressed as the following convex combination of $c_{ip}^{U,\lambda}$ and W_p:

$$W_{d^i mp} = \kappa(\varsigma_{d^i mp})c_{ip}^{U,\lambda} + \left(1 - \kappa(\varsigma_{d^i mp})\right) W_p, \quad \kappa(\varsigma_{d^i mp}) \in (0, 1]. \tag{5}$$

$\kappa(\varsigma_{d^i mp})$ is the input pricing rule depending on $\varsigma_{d^i mp}$. The third assumption is that the pricing rule is decreasing in $\varsigma_{d^i mp}$ and thus $W_{d^i mp}$ is also decreasing in $\varsigma_{d^i mp}$.[43]

With the internal input pricing rule, the profit of d^i is rewritten as

$$\pi_{d^i mp}^{D} = \left(P_{mp} - c_{d^i mp}^{D-} - \tau(1 - \kappa_{d^i mp})W_p\right) s_{d^i mp} \tag{8}$$

where $\kappa_{d^i mp} = \kappa(\varsigma_{d^i mp})$ and $c_{d^i mp}^{D-} = \tilde{c}_{d^i mp}^{D} + \tau\kappa_{d^i mp}c_{ip}^{U,\lambda}$, which represents the marginal cost of

[42]When vertically integrated cement firms are assumed to choose $W_{d^i mp}$ so as to maximize their downstream firms' profits as assumed by Crawford, Lee, Whinston and Yurukoglu (2018), $W_{d^i mp}$ will be written as a function of $\varsigma_{d^i mp}$ and other local market factors, $W_{d^i mp} = W_{mp}(\varsigma_{d^i mp})$. If information on input prices were available, the validity of this rule could be checked by estimating a reduced-form relationship between the actual $W_{d^i mp}$ and $\varsigma_{d^i mp}$. Unfortunately, the lack of information on $W_{d^i mp}$ means that this test is not possible.

[43]Regarding the functional form of the pricing rule, several specifications are considered. The first is that $\kappa(\varsigma_{d^i mp})$ is a continuous function of $\varsigma_{d^i mp}$:

$$\kappa(\varsigma_{d^i mp}) = 1 - (1 - \varsigma_{d^i mp})^2 \text{ or } \varsigma_{d^i mp}. \tag{6}$$

Second, it is assumed that $\kappa(\varsigma_{d^i mp})$ is a step function that depends on a threshold value (α) of the extent of vertical integration:

$$\kappa(\varsigma_{d^i mp}) = \begin{cases} 1 & \text{if } \varsigma_{d^i mp} \geq \alpha \\ 0 & \text{if } \varsigma_{d^i mp} < \alpha \end{cases} \tag{7}$$

Under this specification, $W_{d^i mp}$ becomes either c_{ip}^{U} or W_p, depending on the value of α (0.5 and 1 are examined).

d^i after the price of cement has been subtracted. This expression is used in the subsequent sections for deriving concrete firms' demand for cement.

Vertically-Unintegrated Concrete Firms Let d^0 denote a vertically unintegrated concrete firm. The difference between a vertically integrated and a vertically unintegrated firm is that vertically unintegrated firm d^0 purchases cement at the market price, W_p. The profit function of firm d^0 operating in market m in p is given by

$$\pi^D_{d^0mp} = \left(P_{mp} - c^{D-}_{d^0mp} - \tau W_p\right) s_{d^0mp} \tag{9}$$

where $c^{D-}_{d^0p}$ includes only $\tilde{c}^D_{d^0p}$, which represents the marginal cost of d^0 after the market price of cement has been subtracted.

Local Concrete Demand For local demand for ready-mixed concrete, the following linear inverse demand curve is assumed:

$$P_{mp} = a_{mp} - bS_{mp} \tag{10}$$

where a_{mp} denotes the demand shifter. Alternative specifications for demand can be considered. However, even when using the widely-used constant price-elasticity demand function, the mean of the estimated price-elasticities is close to the estimated price-elasticity obtained in the linear demand function. The above linear demand function is preferred because of its simplicity.[44]

[44] As will be clear, for instance, employing a constant-elasticity demand curve in the framework here would be much more involved because the aggregated demand for cement under that specification becomes a non-linear form. Therefore, while using a constant-elasticity demand curve would not be impossible, using demand functions other than linear ones makes the entire estimation procedure more complicated.

6.4 Market Outcomes and Derived Demand for Cement

To determine market outcomes, it is necessary to make assumptions with regard to the form of competition in the ready-mixed concrete market. When considering the form of competition in these markets, one thing that should be taken into consideration is that ready-mixed concrete firms can establish a local industry association and firms participating in that association are legally allowed to coordinate their business activities.[45] This institutional feature possibly complicates the task of modeling firm behavior in concrete markets and means that standard equilibrium concepts, such as Cournot equilibrium, may not be applicable.

Against this background, the approach taken here is to employ Cournot competition as a baseline model and, by utilizing accounting information, to check whether characterizing competition in the ready-mixed concrete market as Cournot competition is valid.[46] Additionally, how the final conclusions are affected when using forms of competition other than Cournot will be also investigated as a robustness check. The details of these tests and examinations are provided in the Online Appendix.

Given the assumption of Cournot competition, the equilibrium supply quantity of vertically integrated firm d^i can be written in the following form:

$$s_{d^i mp} = \frac{a_{mp} - (N^D_{mp}+1)c^{D-}_{d^i mp} + c^{D-}_{mp} + \left((N^D_{mp}+1)\kappa_{d^i mp} - (1+\kappa_{mp})\right)\tau W_p}{(N^D_{mp}+1)b} \tag{11}$$

where N^D_{mp} is the number of concrete firms in market m in p, $c^{D-}_{mp} = \sum_{j=0}^{N^U}\sum_{d^j=1}^{N^D_{jmp}} c^{D-}_{d^j mp}$, and

[45] In Japan, the ready-mixed concrete industry is exempt from antimonopoly laws. Typically, firms in the same local market jointly apply for the establishment of a local manufactures' association, and upon approval of the application, they become exempt from antimonopoly laws.

[46] In fact, the analysis in the Online Appendix shows that Cournot competition is indeed a reasonable approximation to firm behavior, judging by accounting estimates of concrete firms' profit margins. A possible reason is that the establishment of an association does not necessarily mean that firms are successful in setting up joint sales activities. There is considerable anecdotal evidence showing that attempts at cooperation failed. When firms engage in joint sales activities, they generally establish a share allocation rule among member firms. However, firms have an incentive to deviate from their allocated shares because of the lack of effective enforcement structures. Consequently, even if firms make attempts to set higher prices, deviation undermines the viability of the joint sales activities, rendering them ultimately ineffective.

$\kappa_{mp} = \sum_{j=0}^{N^U} \sum_{d^j=1}^{N^D_{jmp}} \kappa_{d^j mp}$. Similarly, the equilibrium supply of firm d^0 becomes

$$s_{d^0 mp} = \frac{a_{mp} - (N^D_{mp} + 1)c^{D-}_{d^0 mp} + c^{D-}_{mp} - (1 + \kappa_{mp})\tau W_p}{(N^D_{mp} + 1)b}. \tag{12}$$

Aggregating across unintegrated firms' supply quantities and multiplying these by the cement-concrete ratio, τ, yields the amount of cement demanded in market m:

$$Q^{nv,c}_{mp} = \tau \left(\frac{N^D_{0mp}(a_{mp} + c^{D-}_{mp}) - (N^D_{mp} + 1)c^{D-}_{0mp}}{(N^D_{mp} + 1)b} \right) - \tau^2 \left(\frac{N^D_{0mp}(1 + \kappa_{mp})}{(N^D_{mp} + 1)b} \right) W_p \tag{13}$$

where $c^{D-}_{0pm} = \sum_{d^0=1}^{N^D_{0mp}} c^{D-}_{d^0 mp}$. N^D_{0mp} denotes the number of unintegrated concrete firms in m. By aggregating the derived demand functions across local markets, the aggregate derived demand in p is obtained:

$$Q^{nv,c}_p = \alpha^{nv,c}_p - \beta^{nv,c}_p W_p \tag{14}$$

where $\alpha^{nv,c}_p = \sum_{m=1}^{M_p} \tau \left(\frac{N^D_{0mp}(a_{mp}+c^{D-}_{mp})-(N^D_{mp}+1)c^{D-}_{0mp}}{(N^D_{mp}+1)b} \right)$ and $\beta^{nv,c}_p = \sum_{m=1}^{M_p} \tau^2 \left(\frac{N^D_{0mp}(1+\kappa_{mp})}{(N^D_{mp}+1)b} \right)$.

At this point, it is worth emphasizing that the derived demand function in (14) depends on the extent of vertical integration in market m. The demand shifter, $\alpha^{nv,c}_p$, depends on the number of concrete firms, the extent of vertical integration, and the marginal costs of all concrete firms in m, which include vertically integrated cement firms, because c^{D-}_{mp} contains these cement firms' marginal costs. Similarly, the slope of the derived demand function, $\beta^{nv,c}_p$, depends on the number of concrete firms and the extent of vertical integration. Therefore, the demand curve changes depending on the extent of vertical integration in m. For instance, as the number of vertically integrated concrete firms increases, the slope gets steeper and the market demand shrinks.

Vertically integrated firms demand the amount of cement needed to supply their equilibrium quantities, s_{d^imp}, internally. The demand for firm i's cement in p becomes

$$q_p^v = \tau \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} s_{d^imp}. \tag{15}$$

As in equation (11), this amount is realized as the result of competition in local markets and thus depends on the demand shifters, firms' marginal costs, the number of firms, and the cement price, W_p. This means that the amount of internal cement demand ultimately is influenced by the amount of cement supplied to the external cement market in p. This fact is taken into account when cement firms decide how much they supply to unintegrated concrete firms.

6.5 Other Downstream Industries and Total Cement Demand

Because the ready-mixed concrete industry's demand for cement accounts for over 80% of total cement consumption, one possibility would be to focus solely on that industry's demand and abstract away from other downstream industries. However, because the demand of other industries taken together is not negligible (even though demand of individual sectors is very small), ignoring these industries altogether may not be appropriate. On the other hand, because of a lack of detailed information on firms in these industries, constructing models to explain how demand arises would not be very fruitful, since important parameters cannot be estimated.

Therefore, instead of detailing how demand in these industries arises, their demand is simply summarized as a demand curve. That is, it is assumed that other industries' cement demand can be expressed as the following demand function:

$$Q_p^{nv,o} = \alpha_p^{nv,o} - \beta^{nv,o} W_p \tag{16}$$

where $Q_p^{nv,o}$ is the total amount of cement consumed by firms in industries other than the ready-mixed concrete industry. $\alpha_p^{nv,o}$ contains the number of construction workers, and the amount of construction investment in p as well as prefecture-fixed effects. One distinction from the concrete industry's demand function is that parameters are assumed to be constant across prefectures. If firm behavior in the other industries were precisely modeled, this restriction would not be necessary. It should be noted that this assumption may cause biases and affect the final conclusions of the analysis. However, the total share of the other industries in cement consumption is less than 20% and biases therefore should not be substantial, if they exist at all.

By aggregating the demand functions arising from the ready-mixed concrete markets and the other industries, the total cement inverse demand function is derived:

$$W(Q_p^{nv}) = A_p - B_p Q_p^{nv} \tag{17}$$

where $A_p = \frac{\alpha_p^{nv,c}+\alpha_p^{nv,o}}{\beta_p^{nv,c}+\beta^{nv,o}}$, $B_p = \frac{1}{\beta_p^{nv,c}+\beta^{nv,o}}$, and $Q_p^{nv} = Q_p^{nv,c} + Q_p^{nv,o}$.

6.6 Cement Firms' Decisions

This subsection considers cement firms' decisions with regard to q_{ip}^{nv} and q_{ip}^{v}. Cement firms recognize their market power and choose the level of market supply, q_{ip}^{nv}. A change in q_{ip}^{nv}, which leads to a change in cement price W_p, results in a change in the profits of their vertically integrated concrete firms, mainly because unintegrated concrete firms' marginal costs depend on W_p. As a result, vertically integrated cement firms need to balance the profits gained from their vertically integrated concrete firms and those obtained by selling cement to the prefectural market.[47]

The Lagrangian in (3) is rewritten as follows to reflect that vertically integrated concrete

[47]It is assumed that cement firms perfectly internalize their concrete firms' profits. The Online Appendix examines the cases of non-perfect internalization.

firms' supply quantities and profits depend on W_p:

$$L(\boldsymbol{q}_i^{nv}, \lambda_i) = \sum_{p=1}^{P} \left\{ \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} \left\{ \varsigma_{d^i mp} \pi_{d^i mp}^D (W_p) + (1 - \kappa_{d_i mp})(W_p - c_{ip}^{U,\lambda}) \tau s_{d^i mp}(W_p) \right\} \right\} + \sum_{p=1}^{P} \left\{ (W_p - c_{ip}^{U,\lambda}) q_{ip}^{nv} \right\} + \lambda_i \bar{Q} \overline{\sigma}_i \quad (18)$$

where $W_p = W(Q_p^{nv})$ as in (17), $\kappa_{d_i mp}$ is the input pricing rule, and $\tau s_{d^i mp}(W_p) = q_{d^i mp}^v(W_p)$. Because $q_{ip}^v (= \tau \sum_{d^i=1}^{N_{imp}^D} s_{d^i mp})$ is determined as a function of q_{ip}^{nv} (and q_{-ip}^{nv}), $\boldsymbol{q}_i^v$ is dropped.

The first-order condition (FOC) for q_{ip}^{nv} becomes

$$\sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} \left\{ \varsigma_{d^i mp} \frac{\partial \pi_{d^i mp}^D (W_p)}{\partial q_{ip}^{nv}} + (1 - \kappa_{d^i mp}) \tau \left(\frac{\partial W_p}{\partial q_{ip}^{nv}} s_{d^i mp} + (W_p - c_{ip}^{U,\lambda}) \frac{\partial s_{d^i mp}}{\partial q_{ip}^{nv}} \right) \right\} + \frac{\partial W_p}{\partial q_{ip}^{nv}} q_{ip}^{nv} + (W_p - c_{ip}^{U,\lambda}) = 0. \quad (19)$$

In this FOC, the last two terms are standard. On the other hand, the terms in the bracket represent the effects of vertical integration on q_{ip}^{nv}. The first term in the bracket represents the change in $\pi_{d^i mp}^D$ caused by a change in q_{ip}^{nv}. This effect arises mainly because a change in q_{ip}^{nv} leads to a change in W_p and, as a result, unintegrated concrete firms' marginal costs are affected. The sign of $\frac{\partial \pi_{d^i mp}^D (W_p)}{\partial q_{ip}^{nv}}$ can be positive or negative, depending on the input pricing rule $\kappa_{d^i mp}$, which ultimately depends on cement firm i's stake in d^i, $\varsigma_{d^i mp}$.[48] The second term in the bracket is the sum of the marginal profits of selling cement to vertically integrated concrete firms internally. The sign of $\frac{\partial W_p}{\partial q_{ip}^{nv}}$ is always negative whereas the sign of $\frac{\partial s_{d^i mp}}{\partial q_{ip}^{nv}}$ can be positive or negative, depending on $\kappa_{d^i mp}$. Consequently, the sign of this term also depends on $\kappa_{d^i mp}$.[49]

[48]In the case of a relatively small value of $\kappa_{d^i mp}$, $\frac{\partial \pi_{d^i mp}^D (W_p)}{\partial q_{ip}^{nv}}$ can become positive because $W_{d^i mp}$ largely depends on the market price W_p. Otherwise, the derivative shows a negative sign.

[49]To get an intuition of the role of vertical integration, suppose that all $\kappa_{d^i mp}$ are sufficiently large. In this case, the two terms in the bracket, as a whole, act as as-if additional marginal costs. The more concrete

Aggregating upstream firms' FOCs yields the equilibrium market supply in prefecture p:

$$Q_p^{nv*} = \sum_{i=1}^{N^U} q_{ip}^{nv*} = \frac{N^U A_p - \sum_{i=1}^{N^U} c_{ip}^{U,\lambda} - \sum_{i=1}^{N^U} (\Upsilon_i + \Phi_i)}{B_p(N^U + 1) - \sum_{i=1}^{N^U} \Xi_i}, \tag{20}$$

$$\Upsilon_i = \frac{\tau B_p}{b} \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} \left(2\varsigma_{d^i p} \Delta_{d^i mp} + (1 - \kappa_{d^i mp})\right) \left(\Gamma_{d^i mp} + \tau A_p \Delta_{d^i mp}\right)$$

$$\Phi_i = \frac{\tau^2 B_p}{b} \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} (1 - \kappa_{d^i mp})(A_p - c_{ip}^{U,\lambda}) \Delta_{d^i mp}$$

$$\Xi_i = 2\frac{(\tau B_p)^2}{b} \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{ip}^D} \left\{\varsigma_{d^i mp} \Delta_{d^i mp} + (1 - \kappa_{d^i mp})\right\} \Delta_{d^i mp},$$

where $\Delta_{d^i mp} = \frac{(N_{mp}^D+1)\kappa_{d^i mp} - (1+\kappa_{mp})}{(N_{mp}^D+1)}$ and $\Gamma_{d^i mp} = \frac{a_{mp} - (N_{mp}^D+1)c_{d^i mp}^{D-} + c_{mp}^{D-}}{(N_{mp}^D+1)}$. With this equilibrium output Q_p^{nv*}, the equilibrium quantity of firm i is given by

$$q_{ip}^{nv*} = \frac{A_p - c_{ip}^{U,\lambda} - \Upsilon_i - \Phi_i}{B_p} + \left(\frac{\Xi_i}{B_p} - 1\right) Q_p^{nv*}. \tag{21}$$

Once Q_p^{nv*} and W_p^* are determined, the successive oligopolies model means that vertically integrated and unintegrated concrete firms' equilibrium supply quantities, $s_{d^i mp}$ and $s_{d^0 mp}$, are determined accordingly. Concrete firm d^i demands the amount of cement necessary to supply its equilibrium quantity, $\tau s_{d^i mp} (= q_{ip}^v)$. Consequently, q_{ip}^{v*} is determined as a function of q_{ip}^{nv} and other cement firms' market supply quantities.

7 Estimation

Demand for Ready-Mixed Concrete When estimating the demand function, there is one data issue. As explained in Section 5, local market quantities are not available, whereas local concrete prices and demand shifters are available. Because of the lack of local market-level quantity information, the aggregate demand in prefecture p (aggregated across local

firms a cement firm owns in a prefecture, the less it supplies to the prefecture.

markets) is estimated instead. The aggregate demand function is the sum of all local market demand functions in p:

$$S_{pt} = \breve{a}_0 + \breve{a}_1 Z_{pt} - \breve{b} P_{pt} + \epsilon_{pt} \tag{22}$$

where $S_{pt} = \sum_{m=1}^{M_p} S_{mpt}$, $Z_{pt} = \sum_{m=1}^{M_p} Z_{mpt}$, $P_{pt} = \sum_{m=1}^{M_p} P_{mpt}$, and $\epsilon_{pt} = \sum_{m=1}^{M_p} \epsilon_{mpt}$. S_{mpt} and P_{mpt} denote the quantity demanded and the price in local market m in prefecture p at time t, while Z_{mpt} is the demand shifter, which is the number of construction workers in market m at t. When estimating (22), the parameters are assumed to be identical across local concrete markets. Admittedly, this assumption arising from the data limitation may be a drawback of this estimation approach.[50]

The prefecture-level price of gasoline is used as an instrumental variable. The reason is that a change in the fuel price affects the costs of delivering concrete to construction sites. In addition, the gasoline price also influences the delivery costs of cement firms and, in turn, affects the market price of cement, W_{pt}, which is a component of the marginal costs of concrete firms.

Table 5 presents the estimation results of the concrete demand function (22). There are two specifications that use different sets of time- and prefecture-fixed effects. The preferred specification is the specification using only time-fixed effects. The reason is that the average of the estimated price elasticities in this specification is about 0.67, which is a reasonable size, given that the demand for concrete is relatively inelastic.[51] On the other hand, the other specification including both prefecture- and year-fixed effects produces an unreasonably high price-elasticity.

[50]That said, the assumption that demand parameters are identical across markets is very often made in empirical studies.

[51]Another widely-used demand function is a constant-elasticity demand function. When this specification is employed, a similar but slightly higher price elasticity is obtained.

Ready-Mixed Concrete Firms' Marginal Costs With the estimated concrete demand function, ready-mixed concrete firms' marginal costs are recovered using the FOCs for profit maximization under the assumption of Cournot competition,

$$\hat{c}^{D}_{d^i mpt} \quad = \quad \hat{P}_{mpt} + \frac{\partial \hat{P}_{mpt}}{\partial s_{d^i mpt}} s_{d^i mpt}. \tag{23}$$

For vertically unintegrated concrete firm d^0, the estimate of $c^{D-}_{d^0 mpt}(= \tilde{c}^{D}_{d^0 mpt})$ in (9) is obtained as $\hat{c}^{D}_{d^0 mpt} - \tau W_{pt}$. Similarly, for vertically unintegrated concrete firm d^i, the estimate of $c^{D-}_{d^i mpt}(= \tilde{c}^{D}_{d^i mpt} + \tau \kappa_{d^i mpt} c^{U,\lambda}_{ipt})$ in (8) is obtained as $\hat{c}^{D}_{d^i mpt} - \tau(1 - \kappa_{d^i mpt})W_{pt}$.

The mean of price-cost margins under this assumption is around 10%. The validity of the Cournot assumption is checked in the Online Appendix, using accounting information on the price-cost margins of ready-mixed concrete firms. Additionally, other forms of firm conduct are examined to see how the final results are affected by different assumptions about concrete firms' behavior.

That said, it is worth briefly mentioning the results obtained in the Appendix. First, it can be said that Cournot competition is, in fact, a reasonable approximation to competition in local concrete markets. Second, even when different, less competitive levels of firm conduct are assumed, the final conclusions obtained in the analysis below remain qualitatively unchanged.

Other Downstream Industries' Demand for Cement As explained in the previous section, instead of detailing firm behavior in other downstream industries, the following demand function is estimated:

$$Q^{nv,o}_{pt} = Z_{pt}\alpha^{nv,o} - \beta^{nv,o} W_{pt} + \epsilon^{nv,o}_{pt} \tag{24}$$

where $Q^{nv,o}_{pt}$ is the total amount of cement demanded in industries other than the ready-mixed concrete industry. $Z^{nv,o}_{pt}$ is a vector of the demand shifters, which includes the number of construction workers and the amount of construction investment as well as time dummies. The prefecture-level price of gasoline is used as an instrumental variable. As explained earlier, the fuel price is one of the cost shifters in the cement delivery stage.

The estimation results are presented in Table 6. As in the case of ready-mixed concrete demand, two specifications are used. These specifications produce different estimates of the parameters of the demand function. The preferred specification is the specification using only time effects. The reason is that the average of the estimated price elasticities in this specification is about 2.3, whereas the other specification produces an unreasonably high price elasticity.

Total Demand for Cement By plugging estimates of $c^{D-}_{d^i mpt}$ and $c^{D-}_{d^0 mpt}$ into (14), the derived demand for cement is estimated. Combining the demand function derived and the demand function of the other downstream industries produces the total (market) demand for cement. The mean of the price-elasticities is about 0.8. This falls within a reasonable range, given that cement demand is relatively price inelastic.

Cement Firms' Marginal Cost Functions Cement firms' marginal costs are recovered by solving their profit maximizing conditions with respect to the marginal costs. The quantity supplied by cement firm i to cement market p reveals its underlying marginal cost c^U_{ipt}. However, under collusion, cement firms' supply is restricted by the quotas allotted to them. This fact means that, by inverting the first order optimality condition for q^{nv}_{ipt}, what can be obtained is the estimate of the effective marginal cost of firm i, $c^{U,\lambda}_{ipt} = c^U_{ipt} + \lambda_{it}$. Formally, $\hat{c}^{U,\lambda}_{ipt}$ is recovered as follows:

$$\hat{c}^{U,\lambda}_{ipt} = W_{pt} + \frac{\sum_{m=1}^{M_p} \sum_{d^i=1}^{N^D_{impt}} \left\{ \varsigma_{d^i mpt} \frac{\partial \hat{\Pi}^D_{d^i mpt}}{\partial q^{nv}_{ipt}} + (1 - \kappa_{d^i mpt}) \frac{\partial \hat{W}_{pt}}{\partial q^{nv}_{ipt}} \tau s_{d^i mpt} \right\} + \frac{\partial \hat{W}_{pt}}{\partial q^{nv}_{ipt}} q^{nv}_{ipt}}{\left(1 + \sum_{d^i=1}^{N^D_{d^i mpt}} (1 - \kappa_{d^i mpt}) \tau \frac{\partial \hat{s}_{d^i mpt}}{\partial q^{nv}_{ipt}} \right)}. \tag{25}$$

The key objective in the estimation is to break down the effective marginal cost into the actual marginal cost, c^U_{ipt}, and the shadow price, λ_{it}. To this end, the period after the cartel is leveraged. As an antitrust penalty, the JFTC monitored cement firms for three years (1991-1993) by requiring them to report their sales activities (on a monthly basis). It can be assumed that during this period, cement firms' conduct was competitive. Under the assumption of Cournot competition taking place in 1991-1993, λ_{it} is measured as the difference between the marginal cost at time t (during collusion) and in the JFTC monitoring period.[52]

The marginal cost function of firm i is specified as follows:

$$c^U_{ipt} = w_{ipt}\gamma_1 + v_{it}\gamma_2 + z_{pt}\gamma_3 + \eta_i + \psi_p + \epsilon_{ipt}$$

where w_{ipt} is a firm-prefecture-level variable, the number of firm i's service stations, whereas v_{it} is a firm-level variable, plant productivity. z_{pt} includes fuel prices, consisting of the price of gasoline, which is mainly used in the distribution stage, the price of coal, which is used in the production stage, and the price of fuel oil, which is used for shipping cement from plants in other parts of the country to the Chugoku region. Coal and fuel oil prices are time-variant but identical across prefectures, whereas gasoline prices vary over time and across prefectures. η_i represents firm fixed effects capturing firms' unobserved efficiency level, which can be identified based on the JFTC's monitoring period, while ψ_p is prefecture fixed effects.

λ_{it} can be specified in several ways. The most straightforward and flexible specification is firm-time effects during the period of the cartel. The values of these fixed effects, which are measured relative to firm fixed effects η_i, represent shadow marginal costs. On the other hand, the simplest but most restrictive specification is time effects during the cartel, $\lambda_{it} = \lambda_t$. In this specification, all cement firms face the same shadow marginal cost in t.

[52] A potential concern regarding this estimation approach is the possible presence of a time-varying unobserved factors. In particular, if an unobserved cost factor systematically differs between the cartel and post-cartel periods, it is included in the estimates of shadow marginal costs. The Online Appendix discusses this potential issue in detail.

The last specification is a specification that lies between the two. In this case, shadow prices are represented by time effects (during the cartel) and the interaction terms between these effects and a firm-specific variable. As previously explained, the cartel essentially used the pre-cartel market shares to determine quotas. In order to reduce the total level of cement supply while maintaining the pre-cartel market shares, bigger firms needed to reduce the amount of supply more. This implies that shadow marginal costs should depend on the pre-cartel market shares. To reflect this fact, interaction terms between time effects (during the cartel) and the pre-cartel market shares (in 1984) are used to represent λ_{it}, that is, $\lambda_{it} = \lambda_t + \lambda_t \times Share_{i1984}$.[53] [54]

Table 7 presents the estimation results of the cement firms' marginal cost functions. Cement firms' marginal costs depend on $\kappa(\varsigma_{d^i mpt})$, as indicated in (25), and thus different input pricing rules produce different results. However, these estimation results are quite similar to each other both qualitatively and quantitatively. Therefore, to understand the estimation results, focus on column (c) in (1) of Table 7, which will be used as the preferred empirical model.

First, the number of service stations is an important factor affecting cement firms' marginal costs, as expected. The larger the size of a firm's distribution network, the more efficiently the firm can supply in prefecture p. Typically, this efficiency gain is achieved by coordinating cement deliveries across service stations in different locations and avoiding costly long-haul deliveries. On the other hand, although the coefficient on productivity is positive, it is not statistically significant, which is a little bit surprising. One possible reason is that firm-fixed effects already capture much of the variation in productivity.

Some of the coefficients on fuel prices are statistically insignificant and, contrary to

[53] A different but similar variable could be used. Specifically, the size of each cement firm's distribution network in the Chugoku region, represented by the number of service stations, could be used as an alternative variable for firm heterogeneity. Doing so, the results, not surprisingly, are essentially identical to those using pre-market shares, since the two variables are closely related.

[54] To examine which specification is best, a model selection based on the market share predictions is conducted in the Online Appendix. Based on the comparison of the goodness-of-fit measures, the last specification is chosen as the preferred one. The test also indicates that the internal input pricing rule $\kappa(\varsigma_{d^i mpt}) = 1 - (1 - \varsigma_{d^i pmt})^2$ is the best among the candidate pricing rules.

expectation, have a negative sign. The reason for these results is that fuel prices are highly correlated with each other, so that it is difficult to precisely estimate their individual effects. In fact, these fuel prices jointly have statistically significant effects (the F-statistic is 2.79).

8 The Price Effects of the Cartel

Although not the main interest of the present paper, measuring the cartel's price effects is important to get a sense of the extent to which the cartel actually distorted market outcomes. Here, the actual cartel prices are compared with two benchmarks: (Cournot) competitive and perfectly collusive prices. Cournot competitive prices are computed by eliminating the (estimated) shadow marginal costs, while perfectly collusive prices are obtained as the result of firms' joint profit maximizing behavior without any constraints. The computational details are provided in the Online Appendix.

As shown in Figure 1, the cartel raised prices by around 10-26% when compared with the competitive price.[55] In 1985, cement prices were around 18% higher than the competitive price, rising to a peak in 1987, when they were 25% higher than the competitive price. After the peak, cement prices gradually decreased.

An interesting result is the difference between the actual and perfectly collusive prices. If collusion between the firms had been perfect, the cartel prices would have been around 50-60% higher than the competitive prices. This result hints at the presence of constraints preventing the cartel from fully maximizing firms' profits. Possible candidates for such constraints are firms' incentive compatibility constraints and the risk of detection and antitrust penalties. Exploring which factors were actually relevant to the cartel's behavior is undoubtedly interesting and important. However, this is beyond the scope of the present paper and left for future research.

[55] The input pricing rule $\kappa(\varsigma_{d^i mpt}) = 1 - (1 - \varsigma_{d^i mpt})^2$ is used for this exercise. Other pricing rules produce similar results. The year 1990 is excluded because the cartel ended in the middle of this year.

9 Analysis of the Incentive to Collude

This section analyzes the relationship between vertical integration and the incentive to collude. To this end, the critical discount factors under the actual and counterfactual market structures are calculated and compared. First, a counterfactual situation where vertical integration is eliminated altogether is considered. Next, a set of further vertical integration scenarios is considered to see whether different vertical mergers affect incentive to collude differently.

9.1 The Critical Discount Factor

The critical discount factor required for collusion under market structure scenario s is defined as

$$\underline{\delta}^s = \max\left\{\delta_1^s, \ldots, \delta_N^s\right\}, \quad \delta_i^s = \frac{\Pi_i^{DEV,s} - \Pi_i^{COL,s}}{\Pi_i^{DEV,s} - \Pi_i^{PUN,s}} \tag{26}$$

where $\Pi_i^{DEV,s}$ is the deviation profit of cement firm i and $\Pi_i^{COL,s}$ denotes the cartel profit of firm i. $\Pi_i^{PUN,s}$ represents firm i's profit in the punishment phase where an infinite repetition of Cournot competition is assumed as the punishment scheme.[56] The market shares realized under competition under s are used as the cartel sharing rule.

There are two issues regarding the calculation of $\Pi_i^{COL,s}$ and $\Pi_i^{DEV,s}$. First, although $\Pi_i^{COL,a}$ (where a denotes the actual market structure) can be estimated from the data, cartel profits under the counterfactuals, $\Pi_i^{COL,s}(s \neq a)$, cannot be obtained in the same way. $\Pi_i^{COL,s}$ will be determined as an outcome of the cartel's optimal quantity-setting decision on the total regional supply under s, $\overline{Q}^s$. However, the cartel's quantity-setting behavior is

[56] For simplicity, the monthly averages of demand and cost conditions realized in the year that is chosen to measure firms' incentive are assumed to last forever. The effects of fluctuations in demand and cost conditions on collusion have been studied since Green and Porter (1984) and Rotemberg and Saloner (1986). However, unless demand and cost conditions affect cement firms' vertical integration decisions significantly, this simplifying assumption is expected not to cause a major problem. In fact, cement firms' ownership shares in concrete firms remained mostly unchanged and the number of vertically integrated concrete firms hardly changed during the period of interest.

abstracted away in the theoretical model. Therefore, an alternative way to determine $\overline{Q}^s$ and $\Pi_i^{COL,s}$ needs to be considered.[57]

$\overline{Q}^s$ is defined as the total supply necessary to achieve the same total profit increase as the actual cartel achieved. The total profit increase by the cartel is calculated as follows: $\Delta\Pi^a = \Pi^{COL,a} - \Pi^{PUN,a}$ where $\Pi^{\cdot,a} = \sum_{i=1}^{N} \Pi_i^{\cdot,a}$.[58] Based on this increase, the total collusive profit under s is defined as $\Pi^{COL,s} = \Delta\Pi^a + \Pi^{PUN,s}$ where $\Pi^{PUN,s} = \sum_{i=1}^{N} \Pi_i^{PUN,s}$, which is easy to obtain because this is the competitive profit under s. $\overline{Q}^s$ is calculated as the level of total supply necessary to achieve total profit $\Pi^{COL,s}$. Based on $\overline{Q}^s$, an individual firm's profit, $\Pi_i^{COL,s}$, is calculated given its quota, which is determined as $\overline{Q}^s \overline{\sigma}_i^s$, where $\overline{\sigma}_i^s$ is firm i's market share under s. Details of the calculation of $\overline{Q}^s$ and $\Pi_i^{COL,s}$ are provided in the Online Appendix.

The above definition of $\Pi^{COL,s}$ means that the same profit increase as $\Delta\Pi^a$ is realized in counterfactual s. Therefore, the following counterfactual analysis compares the critical discount factors under different scenarios for the same profit increase.[59] For instance, it examines in which market structure, a or s, it is easier for the cement firms to achieve the same profit increase.

The other issue is the deviation profit of firm i, $\Pi_i^{DEV,s}$. The presence of vertically integrated firms makes the derivation complicated, for the following two reasons. First, it is necessary to define how vertically integrated cement firm i deviates when it is a deviator.

[57]An extended model that incorporates the cartel's decision on the level of total supply would describe the cartel's behavior under the actual environment and could be used to predict $\overline{Q}^s$ under s. Harrington (2004) provides a model of explicit collusion. By extending Harrington's model, it would be possible to build a model to explain the behavior of the cartel in the cement industry. However, this would lead to identification challenges. Firms' marginal cost functions and discount factors, and functions that describe the risk of detection and subsequent antitrust penalties need to be identified. However, while joint-identification of these functions and parameters may not be impossible, it is prohibitively difficult. For instance, identifying both firms' discount factors and marginal costs is challenging, as pointed out in the literature on the estimation of dynamic structural models. In addition, the model would include a function representing antitrust risks, which may include a constant risk that is another constant that would need to be identified. To the best of my knowledge, there has been no work analyzing identification of models of either tacit or explicit collusion.

[58]The percentage increase in the total profit brought about by the cartel is also examined. The results are essentially the same as those obtained using $\Delta\Pi^a$.

[59]In contrast, in standard analyses of the incentive to collude, joint profit maxima are used as collusive profits. However, using joint profit maxima is not suitable here. The reasons are discussed in the Online Appendix.

Second, it is necessary to define how vertically integrated cement firms react to a deviation by firm j (regardless of whether j is vertically integrated or not). In other words, the question is how to define the deviation profit of firm j facing vertically integrated cement firms. To resolve these issues, the present paper borrows the ideas employed in Nocke and White (2007) and Normann (2009). Regarding the deviation of vertically integrated cement firm i, it is assumed that the firm deviates in both the upstream and downstream stages by expanding its market supply and reducing the internal input prices for its concrete firms. As for firms' reactions to firm j's deviation, it is assumed that vertically integrated cement firms can react to the deviation at the downstream stage immediately after they become aware of firm j's deviation in the upstream stage. Deviator j anticipates these firms' reactions when it contemplates deviating.[60] Details of how $\Pi_i^{DEV,s}$ and $\Pi_j^{DEV,s}$ are derived are provided in the Online Appendix.

9.2 Analysis of Vertical Integration

Table 8 presents the critical discount factors under the actual market structure and the counterfactual market structure without vertical integration. The total profit increase in 1987, when the cartel's profit reached its peak, is used to calculate these discount factors. For the calculation, it is assumed that the demand and supply conditions in that year last forever.[61]

In the actual market, Nippon Steel Chem.'s discount factor, 0.39, becomes the critical discount factor, whereas in the counterfactual, the critical discount factor, which is also Nippon Steel Chem.'s discount factor, is 0.47. Therefore, vertical integration between cement and ready-mixed concrete firms, as a whole, reduces the critical discount factor, meaning that, under the counterfactual environment, the cement firms find it more difficult to sustain the same level of total profit increase, $\Delta\Pi_{1987}^{a}$.

[60] These firms' reactions ultimately take the form of a change in the (residual) derived demand curve facing the deviating firm, since the demand curve depends on concrete firms' marginal costs, part of which are vertically integrated firms' internal cement prices.

[61] Exercises using other years produce qualitatively similar results.

For reference, the critical discount factors required for supporting the joint profit maximum are presented. As in the above case, vertical integration reduces the critical discount factor. An interpretation of this result is that there is a range of discount factors where the actual market is perfectly collusive, but the counterfactual market is not.

How Does Vertical Integration Affect the Cartel Incentive? The above exercise makes it clear that vertical integration in the cement and concrete markets reduced the critical discount factor. However, the underlying forces that lead to the result are not clear. To understand these forces, this analysis simulates, for every cement firm, the situation where only firm i is allowed to integrate the concrete firms that it actually owns. This analysis isolates each firm's vertical integration from other firms' integration to understand how it affects its own and other firms' incentive to collude by looking at changes in the punishment and deviation profits.

Table 9 presents the effects of vertical integration of firm i (while assuming other firms remain unintegrated) on the critical discount factors of this firm and other firms and their punishment and deviation profits.[62] In all cases, the critical discount factor of the cement firm involved in vertical integration increases whereas those of other cement firms decrease. To examine why vertical integration by a cement firm affects the firm itself and other firms in the opposite directions, take a closer look at changes in the punishment and deviation profits.

First, the effects of firm i's vertical integration on the punishment and deviation profits of this firm are examined. In all cases, these profits of firm i are greater when it is vertically-integrated. There are two reasons. The first is that the profits of firm i's concrete firms are added to its profit. Additionally, because double marginalization is (at least partly) eliminated by vertical integration, these concrete firms become more efficient and consequently make larger profits.

[62] The punishment and deviation profits are measured relative to the collusive profits. Although the same profit increase is used, each firm's cartel profit can differ across different market structures because firms' market shares (in competition) can differ and lead to different quotas.

Second, turning to the effects of firm i's vertical integration on other firms' profits, the main point is that it reduces the deviation profits of other cement firms.[63] The reasons are as follows. Because the vertically-integrated concrete firms of firm i do not participate in cement markets, the market demand curve is steeper. Therefore, the marginal revenue of deviant firm j decreases to a greater extent (holding other firms' market supply constant).[64] Additionally, firm i can respond to firm j's deviation by reducing the internal cement prices it charges its concrete firms after detecting the deviation in the upstream stage. This reaction reduces firm j's deviation profit further.

In summary, vertical integration has the following two countervailing effects. On the one hand, the critical discount factor of firm i increases as a result of vertical integration, because the firm's punishment and deviation profits increase. On the other hand, the critical discount factors of other cement firms decrease, mainly because their deviation profits decrease. The first effect is akin to the punishment effect found by Nocke and White (2007) and Normann (2009). The second effect corresponds to a combination of the outlets effect and the reaction effect, both of which were also found by them.

Next, it is examined how the critical discount factors change when the market structure moves from that where only cement firm i has vertically integrated concrete firms to the actual market structure. In this transition, vertically integrated firm i is affected by other firms' vertical integration. Table 10 presents the transitions from the market structure with no vertical integration (No VI) to the counterfactuals where only firm i is allowed to integrate concrete firms (Own VI) to the actual market (VI). From No VI to Own VI, the critical discount factor of firm i increases, as already explained. From Own VI to VI, firm i is affected by the vertical integration of other firms and its critical discount factor is substantially reduced. The main reason is that the deviation profit of a firm is reduced by the vertical integration of other firms.

[63] The punishment profits of other firms are affected negatively, although this effect is relatively small.

[64] Vertical integration affects the total market supply of vertically integrated firm i because it changes firm i's profit maximizing market supply, q_{ip}^{nv}, leading to a change in the total market supply.

Lastly, let us focus on changes in the critical discount factor of Nippon Steel Chem. Because this firm did not own any concrete firms, there are no own vertical integration effects. Instead, this firm is solely affected by the vertical integration of other cement firms. Therefore, the reduction in its deviation profit is the main reason that vertical integration in the cement and concrete markets facilitated the cement cartel.

9.3 Analysis of Hypothetical Vertical Mergers

The previous analysis revealed that when a cement firm vertically integrates concrete firms, this has two opposing effects on upstream collusion. The critical discount factor of the integrated cement firm increases, while those of other firms decrease, as seen in Table 9. This result suggests the following interesting possibilities, which lead to important policy insights into vertical integration. Suppose there is a hypothetical vertical merger. If a cement firm with the critical discount factor $\underline{\delta}^a$ integrates a concrete firm, this may make upstream collusion more difficult by increasing the critical discount factor. In contrast, if a cement firm with δ_i^a far below $\underline{\delta}^a$ integrates a concrete firm, this merger may facilitate collusion by reducing the critical discount factor. Thus, whether a vertical merger facilitates or hinders collusion depends on which cement firm is involved in the vertical merger.

To examine these scenarios, a counterfactual exercise is conducted. In the exercise, an unintegrated concrete firm (in an unintegrated concrete market) whose size corresponds to the median of vertically integrated concrete firms is chosen, and various counterfactual scenarios in which this concrete firm is merged with cement firms are considered. In each scenario, one of the cement firms and the concrete firm merge, while the vertical integration status of firms is held constant. For all cement firms, the hypothetical vertical merger scenarios are examined and the critical discount factors are compared.

Table 11 presents the results. As expected, different hypothetical vertical mergers have different effects on upstream collusion. For instance, a vertical merger of Nippon Steel Chem. hinders upstream collusion. Although Nippon Steel Chem.'s critical discount factor is still the highest under this counterfactual scenario, its value is higher than in the actual scenario. A similar result is obtained under the scenarios of the vertical mergers of Aso and Mitsubishi. The critical discount factor of Aso (Mitsubishi) becomes highest instead of Nippon Steel Chem.'s, when Aso (Mitsubishi) integrates the concrete firm. More importantly, the critical discount factor increases, meaning that these vertical mergers hinder upstream collusion.

In contrast to these three cases, the vertical mergers of the remaining cement firms have almost no impact on upstream collusion. On the one hand, the critical discount factor of the firm involved in the vertical merger before the merger is so low that it cannot become highest after the merger. On the other hand, the critical discount factors of other firms decrease. However, this effect is negligibly small. Consequently, these mergers have no substantial impact on upstream collusion.[65]

This exercise is designed to provide an example where some vertical mergers hinder collusion whereas others do not. The results are not robust (for instance, in scenarios where cement firms integrate more concrete firms, all mergers hinder collusion). Nevertheless, the results obtained here have important implications for antitrust policy, since they highlight the importance of firm and merger heterogeneities in evaluating the coordinated effects of vertical integration. This point has not been studied well in the literature, despite the fact that, in almost all real-world industries, firms are heterogeneous, like the cement firms examined in this analysis.[66]

[65]These results are similar those obtained in the literature on the coordinated effects of horizontal mergers. For instance, Compte, Jenny, and Rey (2002) find that, when a merger exacerbates the asymmetry in capacities, it hurts collusion. Similarly, Vasconcelos (2005) shows that, when a merger increases the inequality of asset holdings, it hinders collusion.

[66]Nocke and White (2007) and Normann (2009) abstract away from firm heterogeneities. On the other hand, in a later study, Nocke and White (2011) introduce size heterogeneities among downstream firms. When an upstream firm merges with a larger downstream firm, the vertical merger reduces the critical discount factor more than when the upstream firm merges with a smaller firm.

10 Conclusion

The present study focused on a cartel in the Japanese cement industry and explored how vertical integration affects cement firms' incentive to collude. The first analysis showed that vertical integration, as a whole, reduces the critical discount factor, mainly because of the effect of vertical integration on the deviation profits. The second analysis highlighted that different vertical mergers can have different effects on collusion. These findings lead to a better understanding of the link between vertical integration and collusion. In particular, the second analysis provides an important insight into competition policy: considering merger characteristics is essential in determining whether a vertical merger facilitates or hinders collusion.

Finally, some limitations of the present study as well as avenues for future research should be mentioned. First, as pointed out by Asker and Nocke (2021), it has not been shown that there is a unique mapping from the critical discount factor to the likelihood of collusion. Even if the critical discount factor is smaller in one market structure than another, this does not necessarily mean that firms in that market are more likely to collude. In this sense, the results obtained here should be regarded with caution. Second, in cases of illegal or explicit collusion, vertical integration may have another effect. While it is generally assumed that downstream firms in vertically-related markets become whistleblowers against upstream cartels, this may no longer be the case when they are vertically integrated. This change can affect the risk of detection and alter upstream firms' incentive to collude.

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Table 1: Cement Firms' Market Shares in the Chugoku Region

	1984	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	1991	1992	1993
Onoda	21.9	21.5	21.7	21.8	22.4	21.8	22.2	22.7	22.0	21.8
Ube	20.1	20.0	19.2	19.7	20.2	20.6	20.2	18.3	18.9	19.0
Tokuyama	16.0	16.3	16.1	16.3	16.6	16.4	16.0	15.3	14.7	14.8
Nihon	12.7	11.7	11.9	11.9	11.5	11.6	12.2	12.8	12.8	12.3
Mitsubishi	11.3	11.0	11.0	11.4	10.9	11.2	11.6	12.0	12.2	11.1
Sumitomo	8.8	10.1	10.4	9.4	9.1	9.3	8.9	9.1	8.9	9.7
Aso	4.8	4.9	5.1	5.0	4.7	4.8	4.6	5.2	5.4	5.4
Nippon Steel Chem.	3.8	3.9	3.8	4.0	3.9	3.7	3.6	3.6	3.6	3.7
Mitsui	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.7	1.0	1.5

Table 2: Cement Firm in the Chugoku Region in 1985

Cement Firm	Market Share	No. SS	Plant Presence	Productivity	Region/Total	No. Integrated Concrete Firms		
						Total	> 50%	100%
Aso	4.9	5	No	6.1	12.8	5	0	0
Mitsubishi	11.1	7	No	15.5	6.7	13	9	9
Nihon	11.7	7	No	10.1	6.6	20	5	2
Onoda	21.6	11	Yes	13.1	8.5	21	7	2
Nippon Steel Chem.	4.0	3	No	6.0	16.1	0	0	0
Sumitomo	10.2	6	No	11.5	6.9	0	0	0
Tokuyama	16.4	10	Yes	14.7	21.7	17	6	5
Ube	20.1	8	Yes	9.2	11.7	18	7	2

No. SS is the number of service stations. Plant Presence indicates whether cement firms have producing plants in the region. Productivity is the capacity-share weighted average of labor productivity of producing plants from which cement firms ship cement to the region (the unit is 1,000 tonnage). Region/Total shows the share that the Chugoku region accounts for in firms' total national supply.

Table 3: Ready-Mixed Concrete Industry (in 1985)

Prefecture	No. Markets	No. Firms	No. VI Firms			Size Ratio	Const. Workers
				>50%	100%		
Yamaguchi	7	83	25	10	5	1.7	912
Okayama	7	98	21	9	6	1.4	1840
Shimane	4	87	8	2	1	1.7	1163
Hiroshima	8	165	35	12	7	1.8	3195
Tottori	3	32	5	1	1	1.7	326

No.VI Firms is the number of vertically integrated concrete firms. Size Ratio is the size ratio (in terms of capacity) between vertically integrated and unintegrated concrete firms. Const. Workers is the number of construction workers (the unit is 1,000 workers).

Table 4: Summary Statistics

	(1) Cement				(2) Ready-Mixed Concrete		
	No. Obs.	Mean	Std. Dev.		No. Obs.	Mean	Std. Dev.
a. Prefecture (Market) Level				a. Prefecture Level			
Cement Price	36	14084.74	1597.73	Quantity	45	209694.44	97460.46
Quantity	36	36347.09	8776.89	Gasoline Price	45	132.44	9.12
Const. Workers	36	86478.16	18622.16	b. Local Market Level			
Const. Inv.	36	947062.94	468200.45	Concrete Price	261	12583.65	905.26
Gasoline Price	36	131.96	8.92	Const. Workers	261	11928.02	11117.97
Coal Price	36	5276.05	1376.37	c. Firm Level			
Fuel Oil Price	36	27013.81	10561.97	Quantity	4206	2243.52	406.15
b. Firm Level							
Quantity	288	14697.10	9979.52				
No. SS	288	1.73	1.28				
Productivity	288	9.41	0.35				

The units are JPY for cement, concrete, gasoline, coal, and fuel oil prices. The unit is tonnage for cement quantity while the unit is cubic meter (m^3) for ready-mixed concrete. The these annual cement and concrete supply quantities are divided by 12 to convert them monthly variables.

Table 5: Ready-Mixed Concrete Demand Estimation

	(1)	(2)
Concrete Price	-183.689	-1.773
	(33.299)	(0.530)
Const. Workers	43.392	4.132
	(37.154)	(0.388)
Year Effects	Yes	Yes
Prefecture Effects	Yes	No
No. Obs.	45	

Table 6: Cement Demand Estimation

	(1)	(2)
Cement Price	-250.094	-6.127
	(54.138)	(1.476)
Const. Workers	-7.181	0.209
	(12.438)	(0.130)
Const. Inv.	0.082	0.005
	(0.130)	(0.006)
Year Effects	Yes	Yes
Prefecture Effects	Yes	No
No. Obs.	36	

Table 7: Cement Marginal Cost Estimation

	(1) $\kappa_{d^i mpt} = 1 - (1 - \varsigma_{d^i pmt})^2$			(2) $\kappa_{d^i mpt} = \varsigma_{d^i pmt}$			(3) $\kappa_{d^i mpt} = 1$ if $\varsigma_{d^i pmt} = 1$			(4) $\kappa_{d^i mpt} = 1$ if $\varsigma_{d^i pmt} > 0.5$		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
No. SS	-360.164	-359.237	-360.067	-375.897	-375.973	-375.079	-418.376	-417.329	-418.365	-404.265	-404.011	-405.036
	(61.581)	(56.594)	(57.163)	(64.573)	(59.956)	(59.363)	(69.872)	(64.257)	(64.886)	(71.193)	(65.505)	(66.154)
Productivity	56.758	-41.091	-61.408	60.771	-63.737	-41.796	69.439	-37.999	-64.150	60.200	-53.101	-78.688
	(410.653)	(308.008)	(317.118)	(430.604)	(332.609)	(323.074)	(465.941)	(349.711)	(359.962)	(474.750)	(356.504)	(366.993)
Gasoline Price	-58.679	-58.696	-58.681	-60.292	-60.290	-60.306	-64.333	-64.351	-64.333	-63.236	-63.240	-63.222
	(36.542)	(33.723)	(34.054)	(38.317)	(35.717)	(35.372)	(41.461)	(38.289)	(38.654)	(42.245)	(39.032)	(39.409)
Coal Price	-0.153	-0.151	-0.150	-0.164	-0.161	-0.162	-0.185	-0.183	-0.183	-0.188	-0.185	-0.185
	(0.203)	(0.188)	(0.189)	(0.213)	(0.199)	(0.197)	(0.231)	(0.213)	(0.215)	(0.235)	(0.217)	(0.219)
Fuel Oil Price	0.107	0.104	0.103	0.109	0.105	0.106	0.113	0.109	0.109	0.112	0.109	0.108
	(0.052)	(0.047)	(0.048)	(0.054)	(0.050)	(0.050)	(0.059)	(0.054)	(0.054)	(0.060)	(0.055)	(0.055)
Cartel-1985		2914.667	2604.114		2626.967	2961.960		3058.936	2670.345		3059.200	2675.010
		(770.040)	(944.723)		(990.874)	(807.707)		(874.301)	(1072.358)		(891.283)	(1093.306)
Cartel-1986		2599.087	2423.465		2418.481	2606.297		2617.218	2390.219		2624.676	2404.164
		(375.766)	(671.261)		(704.053)	(394.147)		(426.644)	(761.951)		(434.931)	(776.835)
Cartel-1987		3383.677	3085.852		3084.289	3398.780		3428.400	3068.542		3428.594	3073.828
		(215.183)	(594.437)		(623.476)	(225.708)		(244.318)	(674.748)		(249.063)	(687.928)
Cartel-1988		1983.553	1969.532		1973.279	1986.362		1990.698	1963.252		1996.343	1977.837
		(253.982)	(611.083)		(640.935)	(266.405)		(288.370)	(693.642)		(293.971)	(707.192)
Cartel-1989		1480.026	1450.717		1468.794	1498.312		1535.441	1494.165		1538.132	1502.097
		(332.983)	(660.745)		(693.023)	(349.271)		(378.068)	(750.014)		(385.411)	(764.665)
Cartel-1990		960.969	1131.344		1160.633	980.315		1022.140	1219.748		1021.567	1218.710
		(294.976)	(629.223)		(659.961)	(309.404)		(334.914)	(714.233)		(341.420)	(728.185)
Cartel-Time-FirmFE	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No
Cartel-Time-Share1984	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
R^2	0.895	0.894	0.895	0.890	0.889	0.889	0.881	0.880	0.880	0.878	0.876	0.877
No. Obs						288						

$\kappa_{d^i mpt}$ denotes the input pricing rule. No. SS indicates the number of service stations. Productivity is (the logarithm of) labor productivity of cement producing plants from which a firm ships cement to the region (or the mean of labor productivities when a firm uses multiple plants). Cartel-Time is time effects during the cartel. Cartel-Time-FirmFE is time-firm effects during the cartel. Cartel-Time-Share1984 is interaction terms between time effects during the cartel and (the logarithm of) firms' market shares in 1984.

Table 8: Critical Discount Factors

	(1) $\triangle\Pi^a_{1987}$		(2) JPM_{1987}	
	VI	No VI	VI	No VI
Aso	0.37	0.45	0.75	0.79
Mitsubishi	0.36	0.34	0.71	0.71
Nihon	0.28	0.35	0.68	0.71
Onoda	0.17	0.29	0.58	0.67
Nippon Steel Chem.	0.39	0.47	0.76	0.80
Sumitomo	0.22	0.37	0.63	0.73
Tokuyama	0.23	0.32	0.63	0.69
Ube	0.20	0.30	0.61	0.68

The critical discount factors are calculated based the demand and supply conditions realized in 1987. (1) presents the critical discount factors required to support the actual cartel profit increase. (2) presents the critical discount factors required to support the joint profit maximum. VI represents the actual market structure and No VI represents the market structure with no vertical integration.

Table 9: The Effects of Vertical Integration

	(1) Aso			(2) Mitsubishi			(3) Nihon		
	$\triangle\delta_i$	$\triangle\Pi_i^{PUN}$	$\triangle\Pi_i^{DEV}$	$\triangle\delta_i$	$\triangle\Pi_i^{PUN}$	$\triangle\Pi_i^{DEV}$	$\triangle\delta_i$	$\triangle\Pi_i^{PUN}$	$\triangle\Pi_i^{DEV}$
Aso	0.03	0.03	0.03	-0.03	-0.02	-0.04	-0.03	-0.03	-0.03
Mitsubishi	-0.01	0.00	-0.01	0.17	0.08	0.15	-0.05	-0.02	-0.04
Nihon	-0.01	0.00	-0.01	-0.05	-0.02	-0.04	0.08	0.05	0.06
Onoda	-0.01	0.00	-0.01	-0.06	-0.01	-0.03	-0.06	-0.01	-0.03
Nippon Steel Chem.	-0.01	-0.01	-0.01	-0.03	-0.02	-0.04	-0.02	-0.03	-0.03
Sumitomo	-0.01	0.00	-0.01	-0.04	-0.02	-0.04	-0.04	-0.02	-0.04
Tokuyama	-0.01	0.00	-0.01	-0.05	-0.01	-0.04	-0.05	-0.02	-0.04
Ube	-0.01	0.00	-0.01	-0.05	-0.01	-0.03	-0.06	-0.01	-0.03
	(4) Onoda			(5) Tokuyama			(6) Ube		
	$\triangle\delta_i$	$\triangle\Pi_i^{PUN}$	$\triangle\Pi_i^{DEV}$	$\triangle\delta_i$	$\triangle\Pi_i^{PUN}$	$\triangle\Pi_i^{DEV}$	$\triangle\delta_i$	$\triangle\Pi_i^{PUN}$	$\triangle\Pi_i^{DEV}$
Aso	-0.03	-0.02	-0.04	-0.02	-0.02	-0.03	-0.03	-0.03	-0.04
Mitsubishi	-0.05	-0.01	-0.04	-0.04	-0.01	-0.04	-0.05	-0.02	-0.04
Nihon	-0.05	-0.02	-0.04	-0.04	-0.01	-0.04	-0.05	-0.02	-0.05
Onoda	0.07	0.03	0.03	-0.05	-0.01	-0.03	-0.06	-0.01	-0.03
Nippon Steel Chem.	-0.03	-0.02	-0.04	-0.02	-0.02	-0.03	-0.03	-0.03	-0.04
Sumitomo	-0.04	-0.02	-0.05	-0.04	-0.02	-0.04	-0.05	-0.02	-0.05
Tokuyama	-0.05	-0.01	-0.03	0.09	0.04	0.05	-0.06	-0.02	-0.04
Ube	-0.05	-0.01	-0.03	-0.05	-0.01	-0.03	0.08	0.03	0.04

$\triangle\delta_i$ is the difference between the critical discount factor of firm i under firm j's vertical integration δ_i^j ($j \in \{$Aso, Mitsubishi, Nihon, Onoda, Tokuyama, Ube$\}$) and that under no vertical integration δ_i^0. $\triangle\Pi_i^{PUN}$ is the difference between $\check{\Pi}_i^{PUN,j}$ and $\check{\Pi}_i^{PUN,0}$. $\triangle\Pi_i^{DEV}$ is the difference between $\check{\Pi}_i^{DEV,s}$ and $\check{\Pi}_i^{DEV,0}$. $\check{\Pi}_i^{PUN,s}$ and $\check{\Pi}_i^{DEV,s}$ are measured relative to the collusive profit, that is $\check{\Pi}_i^{PUN,s} = \Pi_i^{PUN,s}/\Pi_i^{COL,s}$ and $\check{\Pi}_i^{DEV,s} = \Pi_i^{DEV,s}/\Pi_i^{COL,s}$.

Table 10: Changes in Critical Discount Factors

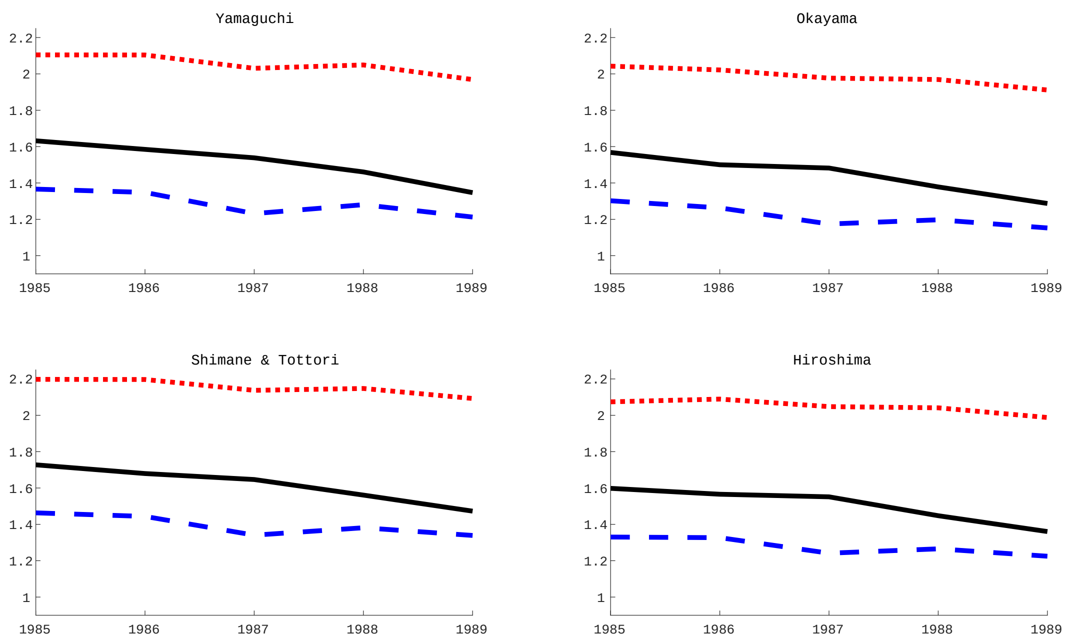
	VI	Own VI	No VI
Aso	0.37	0.47	0.45
Mitsubishi	0.36	0.51	0.34
Nihon	0.28	0.43	0.35
Onoda	0.17	0.35	0.29
Nippon Steel Chem.	0.39	N.A.	0.47
Sumitomo	0.22	N.A.	0.37
Tokuyama	0.23	0.41	0.32
Ube	0.20	0.38	0.30

Table 11: Effects of Hypothetical Vertical Mergers

	VI	Hypothetical Vertical Merger							
		Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.37	0.50	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Mitsubishi	0.36	0.35	0.43	0.35	0.35	0.35	0.35	0.35	0.35
Nihon	0.28	0.28	0.28	0.36	0.28	0.28	0.28	0.28	0.28
Onoda	0.17	0.17	0.17	0.17	0.23	0.17	0.17	0.17	0.17
Nippon Steel Chem.	0.39	0.39	0.39	0.39	0.39	0.52	0.39	0.39	0.39
Sumitomo	0.22	0.22	0.22	0.22	0.22	0.22	0.31	0.22	0.22
Tokuyama	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.30	0.23
Ube	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.26

Figure 1: Price Effects of the Cartel

The top dotted line indicates perfectly collusive prices, while the bottom dashed line indicates Cournot competitive prices. The middle solid line represents the actual cartel prices. The units are 10,000 JPY.



Online Appendix for "How Does Vertical Integration Affect the Incentive to Collude? A Study of Upstream Collusion in Vertically-Related Markets"

Masato Nishiwaki*

July 9, 2024

Contents

*Graduate School of Economics, University of Osaka. E-mail: m.nishiwaki@econ.osaka-u.ac.jp.

A Definition of Concrete Firm

The majority of ready-mixed concrete firms are single-plant firms. However, a non-negligible share are multiple-plant firms. This means that an issue in defining firm is how to treat concrete firms that have plants across different local concrete markets. To deal with such multiple-plant firms, the present study employs the following definition. A concrete firm is identified as a unique plant in a single local concrete market, or a collection of plants in a single market when a concrete firm has more than one plant. For instance, suppose a concrete firm has one plant in one local market and two plants in another market. In this case, the concrete firm is regarded as two individual firms: a single-plant firm in the first local market and a multiple-plant firm in the other market.

B Estimation of the Number of Construction Workers

The estimation of the numbers of construction workers in years other than 1985 and 1990 proceeds as follows. First, regress the number of construction workers on the amount of construction investments, (concrete-)market-fixed effects and trend.

$$y_{mpt} = \beta x_{pt} + \nu_{mp} + \zeta_t + \epsilon_{pmt}, \quad t = 1985, 1990, 1995. \tag{1}$$

y_{mpt} is the number of construction workers in concrete local market m of prefecture p in year t and x_{pt} is the amount of construction investments in prefecture p in year t. ν_{mp} is local market fixed effect and ζ_t represents time-trend. Next, because the amounts of construction investments in p are available every year, the numbers of construction workers can be predicted for years, 1986, 1987, 1988, 1989, 1991, 1992, and 1993, using the estimated parameters in (1).

The numbers of construction workers in prefecture p is estimated as the sum of the estimated numbers of construction workers in local markets in the prefecture.

C Specification For λ_{it}

For the estimation of shadow marginal costs, different specifications for λ_{it} are used. The first specification uses firm-time effects (during the cartel) to represent λ_{it}. The second specification uses only time effects, while the third specification uses time effects and the interaction terms between time effects and the pre-cartel market shares (as of 1984). To examine which specification is best, a model selection based on the market share predictions is conducted.[1] Specifically, the empirical specification for λ_{it} is decided based on the following two types of predicted market shares. The first are market share predictions based on the fitted values of the effective marginal costs ($c_{ipt}^{U,\lambda}$). The second are market share predictions based on the fitted values of the actual marginal costs (c_{ipt}^{U}). That is, in this case, the estimated shadow marginal costs are excluded. The second set of market share predictions are the counterfactual market shares that would have materialized had the cartel not been formed.

The rationale for using not only the market share predictions based on the effective marginal costs but also those based on the marginal costs without shadow marginal costs is as follows. The cartel maintained the pre-cartel market shares. Even in the post-cartel period, the market shares were mostly the same as those in the pre- and cartel periods. These facts imply that shadow marginal costs should play no role in explaining firms' market shares (although they play an important role in reducing

[1]As there is little difference in the R^2 of these specifications, no sizable differences in variables widely used to check model fit, such as market prices and firm supply quantities, can be observed.

quantities supplied). This reasoning leads to the second criterion to evaluate the specification for λ_{it}. If a specification is a good reflection of the cartel's share allocation rule, the market share predictions by the theoretical model based on (the fitted values of) the effective marginal costs, $c_{it}^{U,\lambda}$, will reasonably fit the observed market shares and, additionally, the predictions based on (the fitted values of) the marginal costs, c_{it}^{U}, will reasonably fit the observed market shares as well. Put differently, a good empirical model should fit the actual market shares, regardless of whether the estimated shadow marginal costs are included or not.

The comparison of different specifications for λ_{it} is provided in Table 1. Mean-squared errors (MSE) are used to assess the different specifications. MSE^a is calculated using the market shares predicted by the model with the estimated shadow marginal costs. On the other hand, MSE^c uses the predictions of the model without the estimated shadow marginal costs. The first specification exhibits a poor fit when the estimated shadow marginal costs are eliminated while it fits very well when the estimated shadow marginal costs are included. This result suggests that overfitting occurs under this specification. On the other hand, the last specification fits the data very well, regardless of the presence of estimated shadow marginal costs. As a result, this specification best fits the data. Therefore, based on the comparison of the goodness-of-fit measures, the last specification is chosen as the preferred one.[2]

D Model Fit

Table 2 presents the fit of the structural model presented in the main text. The internal input pricing rule $\kappa(\varsigma_{d^i mpt}) = 1-(1-\varsigma_{d^i pmt})^2$ is used to calculate the model predictions.

[2]The test also indicates that the internal input pricing rule $\kappa(\varsigma_{d^i mpt}) = 1-(1-\varsigma_{d^i pmt})^2$ is the best among the candidate pricing rules.

E Potential Concern Regarding the Estimation of Shadow Marginal Costs

This appendix considers the potential concern regarding the estimation of the marginal cost function and shadow marginal costs. The key assumption is that the period during which the JFTC monitored the cement firms was a period of competition among cement firms. Under this assumption, λ_{it} is estimated as the difference between the marginal cost at time t (during collusion) and in the JFTC monitoring period. One concern regarding this estimation approach is that there may be time-varying unobserved factors. In particular, if an unobserved cost factor systematically differs depending on whether the cartel is in place or has been terminated, it is included in the shadow marginal cost estimates.

One possibility is that, after the cartel was detected, the cement industry returned to normal competition and firm-level and/or industry-level efficiency returned to a competitive level.[3] That is, firms' cost efficiency may have changed as a result of changes in their conduct. If this is indeed the case and changes in efficiency are not captured well, the shadow marginal cost estimates contain factors other than shadow marginal costs.

That said, the analysis in this paper does incorporate plant-level productivity levels, so that any changes in efficiency at the production stage and their impact on marginal costs should be captured. On the other hand, potential efficiency changes at the distribution stage are difficult to measure, except those explained by the number of service stations, and hence are not included among the explanatory variables. Therefore, it is necessary to consider alternative ways of checking whether such changes in unobserved efficiency were really present and, if so, how influential they are in the estimation.

The approach taken here is to allow the parameter on an important variable in the

[3] Backus (2020), for example, examining production plants in the U.S. ready-mixed concrete industry, found that firms that are in more competitive markets are more productive.

marginal cost function to be time-varying and to check whether the parameter changes from one time period to another and how estimates of shadow marginal costs differ from those obtained in the baseline regression analysis in the main text. The most important variable in cement delivery, as outlined in the main text, is the number of firms' service stations in a prefecture. The coefficient on this variable can be interpreted as measuring how efficiently cement firms use their distribution networks in supplying cement. Therefore, if firms became more (or less) efficient and this efficiency gain (or loss) is achieved mainly through improving the use of their distribution networks, that unobserved efficiency change should show up as a change in the coefficient. While this testing approach might not be able to perfectly address the potential issue, at the very least, the time-varying coefficient should capture part of any changes in unobserved factors and reduce the effects of these changes on the shadow marginal cost estimates.

Tables 3 and 4 shows the results. In Table 3, time dummies during the cartel period are interacted with the number of service stations. On the other hand, in Table 4, cartel-firm dummies are interacted with the number of service stations. In the first case, the estimates of the time-varying coefficients are not statistically significant, and in terms of size the coefficient estimates are economically quite small. Therefore, no statistically or economically significant changes overall between the cartel period and the post-cartel period are found. As a result, the shadow marginal cost estimates are hardly affected by the introduction of these interaction terms. On the other hand, in the second case in Table 4, the two variables 'No. SS-Cartel-Nihon' and 'No. SS-Cartel-Ube' have statistically significant and economically sizable effects. Accordingly, the shadow marginal cost estimates change when the interaction terms between the number of service stations and cartel-firm dummies are used. However, more importantly, these changes are not very large.

F Calculation of Collusive and Deviation Profits

F.1 Calculation of $\Pi_i^{COL,s}$

Let $\triangle\Pi^a$ denote an increase in the total profit by the cartel in a particular year (t) under the actual market structure (where a denotes the actual market structure). For counterfactual market structure $s(\neq a)$, first, firms' competitive profits (and market shares) are calculated and, then, the total collusive profit is obtained by adding $\triangle\Pi^a$ to the total competitive profit as follows:

$$\Pi^{COL,s} = \triangle\Pi^a + \Pi^{PUN,s} \tag{2}$$

where $\Pi^{PUN,s} = \sum_{i=1}^{NU} \Pi_i^{PUN,s}$. This collusive profit, denoted by $\Pi^{COL,s}$, is the target for the cartel under s. To achieve $\Pi^{COL,s}$, the cartel determines the total quantity, $\overline{Q}^s$, with the cartel's sharing rule based on the market shares that are realized when firms compete under s, $\overline{\sigma}_i^s$. Each firm maximizes its profit under its quota, $\overline{Q}^s\overline{\sigma}_i^s$. As the result of this constrained profit maximization, each firm's cartel profit is obtained.

This cartel's optimization problem could be solved by searching firms' supply quantities. However, instead of doing so, the shadow marginal costs that achieve the target profit, $\Pi^{COL,s}$, are searched. That is, the problem of searching for firms' supply quantities, $q_i^{v,s}$ and $q_i^{nv,s}$, that achieve $\Pi^{COL,s}$ is reframed to a problem of searching values of the shadow marginal costs that achieves the target profit.[4]

Let $\boldsymbol{\lambda}^{s*} = (\lambda_1^{s*}, \ldots, \lambda_N^{s*})$ denote the vector of shadow marginal costs achieving the target cartel profit and satisfying firms' constraints, that is,

$$\boldsymbol{\lambda}^{s*} = \left\{ (\lambda_1, \ldots, \lambda_N) : \; \Pi^{COL,s} = \sum_{i=1}^{N} \Pi_i^{COL,s}(\boldsymbol{\lambda}), \; \overline{\sigma}_i^s = \sigma_i^s(\boldsymbol{\lambda}) \; \forall i \right\}. \tag{3}$$

[4]The main reason of this indirect optimization procedure is that it is easier to search shadow prices than to search quantities.The reason is that a firm is given one shadow marginal cost whereas it has different (market) supply quantities for each prefecture. For a vector of shadow marginal costs, $\boldsymbol{\lambda}$, there are closed forms for $q_i^{v,s}(\boldsymbol{\lambda})$ and $q_i^{nv,s}(\boldsymbol{\lambda})$ as explained in the section of the theoretical model.

$\Pi^{COL,s}$ is the target total profit. $\overline{\sigma}_i^s$ denotes the market share allocated to firm i. $\sigma_i^s(\boldsymbol{\lambda})$ denotes the share of firm i, that is,

$$\sigma_i^s(\boldsymbol{\lambda}) = \frac{q_i^s(\boldsymbol{\lambda})}{\overline{Q}^s(\boldsymbol{\lambda})} \tag{4}$$

where $q_i^s(\boldsymbol{\lambda}) = q_i^{nv,s}(\boldsymbol{\lambda}) + q_i^{v,s}(\boldsymbol{\lambda})$, $q_i^{nv,s}(\boldsymbol{\lambda}) = \sum_{p=1}^{P} q_{ip}^{nv,s}(\boldsymbol{\lambda})$, and $q_i^{v,s}(\boldsymbol{\lambda}) = \sum_{p=1}^{P} \sum_{m=1}^{M_p} q_{imp}^{v,s}(\boldsymbol{\lambda})$. $\overline{Q}^s(\boldsymbol{\lambda})$ is the total supply.

With $\boldsymbol{\lambda}^{s*} = (\lambda_1^{s*}, \ldots, \lambda_N^{s*})$ at hand, each firm's collusive profit $\Pi_i^{COL,s}(\boldsymbol{\lambda}^*)$ is calculated.

F.2 Calculation of $\Pi_i^{DEV,s}$

In the case of no vertical integration, it is straightforward to define and calculate firms' deviation profits. When it is deviating, a deviant firm tries to capture as much extra profits as possible by supplying beyond its quota, with the expectation of other upstream complying with their quotas. However, vertical integration makes the definition and calculation of the deviation profits of cement firms complicated. First, it is necessary to define the way that vertically-integrated cement firm i deviates. Second, it is also necessary to define how vertically-integrated cement firms react to a deviation by any other cement firm (regardless of this deviant firm is vertically-integrated or not). The first issue is about the deviation profit of vertically-integrated firm i, and the second is about that of cement firm j when (some of) other cement firms are vertically-integrated.

To resolve these issues, the present paper borrows the ideas employed in Nocke and White (2007) and Normann (2009). Regarding the deviation of vertically-integrated cement firm i, it is assumed that the firm deviates in both the upstream and the downstream stages by expanding its market supply and reducing the internal input prices for its concrete firms.[5] More specifically, by ignoring its shadow marginal cost, λ_i^{s*}, firm i supplies to the cement market beyond the amount that it would supply if the firm complied with the cartel's allocation rule, $\overline{q}_i^{nv,s}$. In addition, by ignoring λ_i^{s*} and reducing the cement prices at which firm i's concrete firms are supplied, firm i also increases its (internal) supply to its concrete firms beyond $\overline{q}_i^{v,s}$, which is the amount that firm i would supply if it complied with the allocation rule.

Turning to the second issue of defining the deviation profit of firm j when (some of) other cement firms vertically integrate concrete firms. First, firm j cannot sell cement to the concrete firms of other cement firms. Therefore, the deviant firm cannot gain as much deviation profit as it could without vertical integration (holding other firms' market supply constant). This effect corresponds to what is called the outlets effect in Nocke and White (2007) and Normann (2009).

Second, other vertically-integrated cement firms can start retaliation for firm j's deviation at the downstream stage immediately after they become aware of firm j's deviation in the upstream stage. That is, instead of waiting for the next period, vertically-integrated cement firms react to firm j's deviation by reducing the internal cement prices for their vertically-integrated concrete firms after observing cement market prices (in prefectures) falling below the levels intended by the cartel. These reactions reduce the supply of unintegrated concrete firms because the marginal costs of vertically-integrated concrete firms are reduced. As a result, firm j's deviation profit is reduced by other firms' reactions.[6] This effect corresponds to the reaction effect identified in Nocke and White (2007) and Normann (2009).[7] Deviator j anticipates these vertically-integrated cement firms' reactions when it contemplates deviating.

Formally, the deviation profit of cement firm j in prefecture p (under market struc-

[5]It is assumed that any deviation in the upstream stage triggers a punishment phase so that there is no reason that an integrated cement firm deviates in only the upstream stage.

[6]If firm j is a vertically-integrated cement firm, its concrete firms' supply and the profits of these firms are also reduced by other cement firms' reactions to firm j's deviation in the upstream stage.

[7]This reaction effect arises as a nature of successive oligopolies in which upstream and downstream prices (and quantities) are sequentially determined.

ture s) is defined in the following manner:

$$\Pi_{jp}^{DEV,s}(\boldsymbol{\lambda}_{-j}^{s}, \overline{\boldsymbol{q}}_{-jp}^{nv,s}) = \max_{q_{jp}^{nv}} \sum_{m=1}^{M_p} \sum_{d^j=1}^{N_{jmp}^{D,s}} \left\{ \varsigma_{d^j mp} \pi_{d^j mp}^{D,DEV,s}(\boldsymbol{\lambda}_{-j}^{s}) + (W_{d^j mp} - c_{jp}^{U}) \tau s_{d^j p}^{DEV,s}(\boldsymbol{\lambda}_{-j}^{s}) \right\} + (W_p^s(q_{jp}^{nv,s}, \overline{\boldsymbol{q}}_{-jp}^{nv,s}; \boldsymbol{\lambda}_{-j}^{s}, N_p^{D,s}) - c_{jp}^{U}) q_{jp}^{nv,s} \quad (5)$$

where $\overline{\boldsymbol{q}}_{-jp}^{nv,s}$ denotes a vector of quantities supplied to the cement market in p by other cement firms when they are complying with the cartel allocation rule. $\boldsymbol{\lambda}_{-j}^{s}$ denotes a vector of other cement firms' shadow marginal costs. $W_p^s(q_{jp}^{nv,s}, \overline{\boldsymbol{q}}_{-jp}^{nv,s}; \boldsymbol{\lambda}_{-j}^{s}, N_p^{D,s})$ is the (residual) inverse demand curve facing deviating firm j,

$$W_p^s(Q_p; \boldsymbol{\lambda}_{-j}^{s}, N_p^{D,s}) = A_p^s - B_p^s(q_{jp}^{nv} + \overline{\boldsymbol{q}}_{-jp}^{nv,s}). \quad (6)$$

B_p^s depends on the number of vertically-integrated concrete firms, $N_p^{D,VI,s}$, while A_p^s depends on $\boldsymbol{\lambda}_{-j}^{s}$ (because vertically-integrated concrete firms marginal costs include $\boldsymbol{\lambda}_{-j}^{s}$) as well as $N_{mp}^{D,VI,s}$.[8] Vertical integration affects the residual demand curve by increasing $N_p^{D,VI,s}$. That is, the withdrawal from the prefectural cement market of $-j$'s concrete firms leads to a lower market demand for cement. This effect corresponds to the outlets effect.[9]

Additionally, $\boldsymbol{\lambda}_{-j}^{s}$ is set $\mathbf{0}$ because, in the downstream stage, vertically-integrated firms react to firm j's deviation by ignoring their shadow costs (after observing firm j's deviation in the upstream stage). Consequently, concrete firms that are integrated by other cement firms supply more in the downstream stage due to their reduced input prices.[10] This effect corresponds to the reaction effect, leading to a further reduction in the deviation profit of cement firm j.

[8] A_p^s also depends on λ_j^s if firm j is a vertically-integrated firm. When deviating, this firm ignores this shadow marginal costs and sets λ_j^s equal 0.

[9] The effect of eliminating double marginalization, which affects vertically-integrated concrete firms' marginal costs, also affects the derived demand curve.

[10] $\overline{\boldsymbol{q}}_{-jp}^{nv,s}$ are already determined in the upstream stage and they are not changed in the downstream stage.

F.3 Calculation of Perfect Collusive Profit

Perfectly collusive profit (joint-profit maximum) is defined as a solution to the following maximization problem similar to (3),

$$\max_{\boldsymbol{\lambda}} \sum_{i=1}^{N} \Pi_i(\boldsymbol{\lambda}) \\ s.t.\ \ \overline{\sigma}_{it} = \sigma_i(\boldsymbol{\lambda}) \ \ (i = 1, \ldots, N^U) \tag{7}$$

where $\boldsymbol{\lambda} = (\lambda_1, \ldots, \lambda_N)$. This problem is very similar to (3). The only difference from (3) is the absence of a target cartel profit.

F.4 Reasons Why Joint-Profit Maxima Are Less Suitable

Perfectly collusive profits (or joint-profit maxima) are used as collusive profits in a standard analysis of collusion. Typically, the critical discount factors required for supporting these perfectly collusive profits under different circumstances are examined. However, comparing these critical discount factors is not suitable here due to the following reasons. First, as already examined in the main text, the actual cartel profits are far less than the perfectly collusive profits. Therefore, a situation where the cartel obtained the joint-profit maximum does not reflect the reality. Second, even if the cartel achieved the maximum profit, the joint-profit maximum under the actual market structure with vertical integration is not the same as that under a counterfactual market structure without it because of the presence (or elimination) of double marginalization. Consequently, the critical discount factors cannot be compared for equal profits.[11] Third, quantity-setting behavior in the cement (and concrete) markets is a further

[11] In Nocke and White (2007), the same collusive profit is realized regardless of vertical mergers because upstream firms use two-part tariffs and can always gain the full surplus. The assumption of two-part tariffs enables them to a ceteris paribus analysis of the critical discount factor needed to support collusion that generates the maximum profit. In Normann (2009), linear input prices are assumed and double marginalization is present. Therefore, comparing the critical discount factors in different market structures cannot be made for equal profits.

complicating factor. In the case of price competition, there is a rationale for focusing on the joint-profit maxima because they are supported at the lowest critical discount factors. In this case, it can be interpreted that, if the discount factor in one market structure is less than in the other, there is a range of discount factors where the former market is collusive but the other is not.[12] This interpretation cannot be made here because the joint-profit maximum in the quantity-setting behavior of cement firms does not provide the lowest critical discount factor.

Therefore, in the counterfactual exercises in the main text, the profit increase by the actual cartel, $\Delta\Pi^a$, is used. The critical discount factors required for supporting this profit increase under different market structure scenarios are calculated and compared. In other words, the comparisons of these discount factors are made for equal profit increases instead of equal profits.

G Downstream Competition

In the main text, Cournot competition is assumed to describe the form of competition between ready-mixed concrete firms. As explained there, this assumption may not be appropriate, because concrete firms can establish a local industry association that can play a role in coordinating the sales activities of member firms in the local market. Therefore, it is necessary to check whether Cournot competition is really a reasonable approximation to competition in the ready-mixed concrete markets examined here.

To this end, accounting information is utilized to examine how close the (average) price-cost margins implied by Cournot competition are to accounting estimates of such margins. This approach is similar to the approach taken by Nevo (2001), who compares

[12]Normann (2009) focuses on the collusive profit that requires the lowest critical discount factor in each market structure. Without vertical integration, the joint profit maximum provides the lowest critical discount factor, $\frac{1}{2}$, because price competition between upstream firms is assumed. Even with vertical integration, the joint profit maximum provides the lowest critical discount factor as well. More importantly, the collusive profit is sustained even when $\delta \leq \frac{1}{2}$, meaning that there exists a range of discount factors where the vertically integrated industry is collusive but the separated industry is not.

accounting estimates of the price-cost margins in the U.S. breakfast cereal industry and estimates of price-cost margins obtained using structural models based on different behavioral assumptions.

Accounting estimates of price-cost margins in the ready-mixed concrete industry are taken from the Business Analyses and Statistics by TKC (BAST). The industry average operating profit margins of ready-mixed concrete firms range from 3.4% to 5.2% during the period 1985-1993. However, these operating profit margins include selling, general, and administrative expenses (SGAs). Among these expenses, general and administrative expenses are fixed costs. After these fixed expenses are subtracted from the operating profit margins, the resulting estimate of profit margins becomes around 13-14%.

However, one issue of using the estimates in the BAST is that these figures are based on accounting information for firms in the black. Therefore, the average should be regarded as the truncated-mean of the profit margins of concrete firms. It is likely that the truncated mean is higher than the mean of the entire distribution of concrete firms' profit margins. Therefore, 13-14% should be regarded as an estimate of the upper-bound of the actual profit margins of ready-mixed concrete firms.

The implied average price-cost margin under Cournot competition for the 1985-1993 period is around 10% (the standard deviation is around 2%) and the 95% confidence interval is around 6% to 14%. Comparing this estimate with the accounting estimates of 13-14%, Cournot competition appears to be a reasonable approximation to firm conduct in the local ready-mixed concrete markets examined here (at least on average). Given that the accounting estimates are an upper bound, the 95% confidence interval likely includes the actual (unknown) average of price-cost margins.

In addition to checking the validity of the Cournot assumption, this appendix examines the robustness of the results obtained in the main text. In this robustness check, alternative forms of firm competition are examined to see whether and how the results obtained in the main text change depending on the form of competition assumed. To conduct this type of robustness analysis, a parameter representing the degree of competition between firms is introduced. This approach using a parameter to express competition other than the usual forms of competition is that employed by Weyl and Fabinger (2013), Miller and Weinberg (2017), and Rits (2024).[13]

The robustness analysis here employs a (conduct) parameter to represent the degrees of competition other than Cournot competition. The analysis proceeds as follows. Consider the following first order condition (FOC) for firm d^i's profit maximization problem with conduct parameter η_{pm}:

$$P_{pm} + P'_{pm}(1 + \eta_{pm})s_{d^i pm} = c_{d^i pm} \tag{8}$$

where $s_{d^i pm}$ is the quantity supplied by concrete firm d^i and $c_{d^i pm}$ is the marginal cost of d^i. From the above FOC, for all concrete firms, the marginal costs implied by firm conduct $(1 + \eta_{pm})$ are obtained. With these estimates of concrete firms ' marginal costs, the marginal costs of cement firms are estimated. In the subsequent counterfactual analyses, the presence of η_{pm} gives rise to different market outcomes in both the concrete and cement markets.

Table 5 presents the results.[14] $\eta_{pm} = 0.4$ corresponds to the accounting estimate of the average of price-cost margins. To check how the results change depending on different values of the parameter, η_{pm} is calibrated from 0.1 to 0.4. In addition, the value of $\eta_{pm} = 1$ is also examined. $\eta_{pm} = 1$ corresponds to a situation where the price-cost margin is twice as high as the Cournot level.

The results in Table 5 indicate that the same findings as in the main text are ob-

[13] For instance, in their empirical study, Miller and Weinberg (2017) use a parameter to capture changes in firm conduct from the Bertrand Nash to collusive paradigm after the Miller-Coors joint-venture.

[14] The estimation of the marginal cost function of cement firms are also influenced by the introduction of η_{pm}. However, the estimation results with η_{pm} are not significantly different from those presented in the main text and are therefore not presented here.

tained when using different values of η_{pm} in the range of $[0.1, 0.4]$. Therefore, for a plausible range of the degree of downstream competition, the same results and conclusions as those under the assumption of Cournot competition are obtained.

However, if competition becomes even less intense, the results differ. In the case of $\eta_{pm} = 1$, the opposite result from the main text, namely, that vertical integration, on the whole, makes collusion difficult, is obtained. In addition, regarding hypothetical mergers, all mergers (except those involving Onoda) make upstream collusion more difficult, which is a somewhat different conclusion from that obtained in the main text. These results indicate that the degree of competition in downstream markets is an important determinant of the effects of vertical integration on upstream collusion.

H Frictions between Cement and Concrete Firms

In the model presented in the main text, vertically-integrated cement firm i chooses its market supply, q_i^{nv}, taking into account the effects of q_i^{nv} on the profits of its vertically-integrated concrete firms. In this profit maximization problem, it is assumed that vertically-integrated cement firm i perfectly internalizes the profits of its concrete firms. That is, there is no friction between the vertically-integrated cement and concrete firms. However, in reality, there may be frictions between these upstream and downstream firms that preclude the perfect internalization. The presence of frictions between upstream and downstream firms is pointed out by Crawford, Lee, Whinston and Yurukoglu (2018) in their study of vertical integration in the US multichannel television markets. In their model, the presence of possible intra-firm frictions is taken into account. More concretely, they introduce a parameter to represent the extent to which vertically-integrated firms internalize their affiliate firms' profits, and they estimate the internalization parameter from the data.

Following the idea of Crawford, Lee, Whinston and Yurukoglu (2018), this online appendix introduces a parameter measuring the extent to which vertically-integrated cement firms internalize the profits of their ready-mixed concrete firms, and examines how (possible) imperfect internalization affects the results obtained in the main text. Let μ denote the extent to which internalization within an integrated firm actually occurs. The profit maximization problem of cement firm i becomes as follows:

$$\begin{aligned} L(\boldsymbol{q}_i^{nv}, \lambda_i) &= \sum_{p=1}^{P} \left\{ \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} \left\{ \mu \varsigma_{d^i mp} \pi_{d^i mp}^D (W_p) + (1-\kappa_{d_i mp})(W_p - c_{ip}^{U,\lambda}) \tau s_{d^i mp}(W_p) \right\} \right\} \\ &\quad + \sum_{p=1}^{P} \left\{ (W_p - c_{ip}^{U,\lambda}) q_{ip}^{nv} \right\} + \lambda_i \bar{Q} \overline{\sigma}_i. \quad (9) \end{aligned}$$

From the first order condition for q_{ipt}^{nv}, the effective marginal cost is recovered as

$$c_{ipt}^U + \lambda_{it} = W_{pt} + \frac{\sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{impt}^D} \left\{ \mu \varsigma_{d^i mpt} \frac{\partial \hat{\Pi}_{d^i mpt}^D}{\partial q_{ipt}^{nv}} + (1-\kappa_{d^i mpt}) \frac{\partial \hat{W}_{pt}}{\partial q_{ipt}^{nv}} \tau s_{d^i mpt} \right\} + \frac{\partial \hat{W}_{pt}}{\partial q_{ipt}^{nv}} q_{ipt}^{nv}}{\left(1 + \sum_{d^i=1}^{N_{d^i mpt}^D} (1-\kappa_{d^i mpt}) \tau \frac{\partial \hat{s}_{d^i mpt}}{\partial q_{ipt}^{nv}} \right)}. \quad (10)$$

Further, the above equation is changed to the following form for estimation.

$$c_{ipt}^U + \lambda_{it} - \mu \partial \pi_{ipt}^D = W_{pt} + \frac{\sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{impt}^D} (1-\kappa_{d^i mpt}) \frac{\partial \hat{W}_{pt}}{\partial q_{ipt}^{nv}} \tau s_{d^i mpt} + \frac{\partial \hat{W}_{pt}}{\partial q_{ipt}^{nv}} q_{ipt}^{nv}}{\left(1 + \sum_{d^i=1}^{N_{d^i mpt}^D} (1-\kappa_{d^i mpt}) \tau \frac{\partial \hat{s}_{d^i mpt}}{\partial q_{ipt}^{nv}} \right)} \quad (11)$$

where $\partial \pi_{ipt}^D = \frac{\sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{impt}^D} \varsigma_{d^i mpt} \frac{\partial \hat{\Pi}_{d^i mpt}^D}{\partial q_{ipt}^{nv}}}{\left(1 + \sum_{d^i=1}^{N_{d^i mpt}^D} (1-\kappa_{d^i mpt}) \tau \frac{\partial \hat{s}_{d^i mpt}}{\partial q_{ipt}^{nv}} \right)}$ and $c_{ipt}^U = w_{ipt}\gamma_1 + v_{it}\gamma_2 + z_{pt}\gamma_3 + \eta_i + \psi_p + \epsilon_{ipt}$. In this equation, the parameters of interest are γ, η_i, ψ_p, λ_{it} and μ. These parameters could be joint-estimated with a proper instrumental variable(s).[15] Unfortunately, however, $\partial \pi_{ipt}^D$ is highly correlated with other firm- and firm-prefecture variables. As a

[15] $\partial \pi_{ipt}^D$ is highly likely to be correlated with ϵ_{ipt}. Therefore, an instrumental variable(s) for it is needed. A concrete demand shifter(s), such as the number of construction workers in local concrete markets, is a good candidate for the instrumental variable(s).

result, the joint-estimation of these parameters cannot be implemented.

Therefore, the approach taken here is to calibrate μ and check how the results of the marginal cost function estimation and those of the subsequent counterfactual analyses vary with different values of μ. In this robustness check, μ is calibrated from 0.5 to 0.9.

Table 6 presents the results of the cement firms' marginal cost function estimation. Different values of μ produces different results. However, the differences in the cost parameters are not substantially large. With these estimates, the analysis of the critical discount factor is conducted as in the main text. Table 7 presents the critical discount factors under the actual and counterfactual market structures. Not surprisingly, the conclusions obtained in the main text are qualitatively unchanged (although values of the critical discount factors vary with μ).

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Table 1: Comparing Different Specifications

MSE^a is calculated using the entire sample period (1985-1993). MSE^c is calculated using the period of the cartel (1985-1990). (1), (2), (3) and (4) corresponds to those in Table 7. Similarly, (a), (b) and (c) corresponds to those in the same table.

	(1)			(2)		
	(a)	(b)	(c)	(a)	(b)	(c)
MSE^a	0.053	0.063	0.059	0.051	0.063	0.058
MSE^c	0.064	0.047	0.036	0.072	0.054	0.041
$MSE^a + MSE^c$	0.117	0.110	0.095	0.124	0.117	0.099
	(3)			(4)		
	(a)	(b)	(c)	(a)	(b)	(c)
MSE^a	0.057	0.076	0.064	0.053	0.073	0.060
MSE^c	0.078	0.061	0.046	0.090	0.069	0.053
$MSE^a + MSE^c$	0.135	0.137	0.109	0.143	0.143	0.113

Table 2: Model Fit

Mean absolute deviations are used to measure the fit of the model. For cement firms' market shares, the mean of absolute differences between the actual and predicted market shares is presented. For price and supply quantity, the mean of absolute % differences between the actual and predicted values is presented.

	(1) Full	(2) 1985-1990	(3) 1991-1993
Market Shares			
Aso	0.47	0.22	0.96
Mitsubishi	0.67	0.74	0.54
Nihon	0.39	0.23	0.70
Onoda	0.57	0.47	0.78
Nippon Steel Chem.	0.38	0.26	0.61
Sumitomo	0.60	0.60	0.59
Tokuyama	0.49	0.34	0.78
Ube	0.79	0.41	1.55
Prefectural Cement Price	1.54	1.31	2.01
Prefectural Cement Supply	0.18	0.18	0.20
Local Market Concrete Price	0.42	0.36	0.52
Local Market Concrete Supply	0.34	0.31	0.39

Table 3: Cement Marginal Cost Estimation: Robustness Check (1)

$\kappa(\varsigma_{d^i mpt}) = 1 - (1 - \varsigma_{d^i pmt})^2$ is used as the input pricing rule. The number of observations is 288. The first column shows the result of column (c) in (1) of Table 7 in the main text.

	(1)	(2)
No. SS	-360.067	-369.862
	(57.163)	(77.840)
No. SS-Cartel-1985		-6.645
		(126.780)
No. SS-Cartel-1986		-29.807
		(122.012)
No. SS-Cartel-1987		19.092
		(121.980)
No. SS-Cartel-1988		31.146
		(123.302)
No. SS-Cartel-1989		-2.664
		122.972
No. SS-Cartel-1990		79.028
		(120.794)
Productivity	-61.408	-57.055
	(317.118)	(320.731)
Gasoline Price	-58.681	-58.110
	(34.054)	(38.094)
Coal Price	-0.150	-0.150
	(0.189)	(0.192)
Fuel Oil Price	0.103	0.103
	(0.048)	(0.049)
Cartel-1985	2604.114	2591.786
	(944.723)	(974.925)
Cartel-1986	2423.465	2412.218
	(671.261)	(680.072)
Cartel-1987	3085.852	3093.067
	(594.437)	(603.604)
Cartel-1988	1969.532	1983.100
	(611.083)	(621.952)
Cartel-1989	1450.717	1451.836
	(660.745)	(668.884)
Cartel-1990	1131.344	1152.902
	(629.223)	(639.840)
Cartel-Year-Share1984	Yes	Yes
R^2	0.895	0.895

Table 4: Cement Marginal Cost Estimation: Robustness Check (2)

$\kappa(\varsigma_{d^i mpt}) = 1 - (1 - \varsigma_{d^i pmt})^2$ is used as the input pricing rule. The number of observations is 288. The first column shows the result of column (c) in (1) of Table 7 in the main text.

	(1)	(2)
No. SS	-360.067	-388.731
	(57.163)	(77.247)
No. SS-Cartel-Aso		-125.095
		(157.715)
No. SS-Cartel-Mitsubishi		8.891
		(125.019)
No. SS-Cartel-Nihon		-308.441
		(129.825)
No. SS-Cartel-Onoda		82.141
		(84.368)
No. SS-Cartel-Nippon Steel Chem.		-197.815
		(294.623)
No. SS-Cartel-Sumitomo		-211.750
		(141.352)
No. SS-Cartel-Tokuyama		90.771
		(92.386)
No. SS-Cartel-Ube		-254.675
		(121.367)
Productivity	-61.408	18.444
	(317.118)	(317.017)
Gasoline Price	-58.681	-59.653
	(34.054)	(33.487)
Coal Price	-0.150	-0.154
	(0.189)	(0.185)
Fuel Oil Price	0.103	0.107
	(0.048)	(0.047)
Cartel-1985	2604.114	2869.512
	(944.723)	(981.163)
Cartel-1986	2423.465	2695.543
	(671.261)	(738.873)
Cartel-1987	3085.852	3386.982
	(594.437)	(673.470)
Cartel-1988	1969.532	2268.587
	(611.083)	(692.090)
Cartel-1989	1450.717	1773.868
	(660.745)	(732.334)
Cartel-1990	1131.344	1427.595
	(629.223)	(703.595)
Cartel-Time-Share1984	Yes	Yes
R^2	0.895	0.90

Table 5: Alternative Downstream Competition

(1) $\eta = 0.1$

	VI	No VI	Hypothetical Vertical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.38	0.44	0.49	0.38	0.39	0.39	0.39	0.39	0.39	0.39
Mitsubishi	0.36	0.32	0.36	0.46	0.36	0.36	0.37	0.37	0.37	0.37
Nihon	0.28	0.33	0.28	0.28	0.39	0.28	0.28	0.29	0.29	0.29
Onoda	0.18	0.28	0.18	0.18	0.18	0.26	0.18	0.18	0.18	0.18
Nippon Steel Chem.	0.41	0.47	0.41	0.41	0.41	0.41	0.58	0.42	0.42	0.42
Sumitomo	0.23	0.37	0.24	0.24	0.24	0.24	0.24	0.36	0.24	0.24
Tokuyama	0.24	0.30	0.24	0.24	0.24	0.24	0.24	0.24	0.33	0.24
Ube	0.21	0.28	0.21	0.21	0.21	0.21	0.21	0.22	0.22	0.28

(2) $\eta = 0.2$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.39	0.44	0.52	0.39	0.39	0.40	0.40	0.40	0.40	0.40
Mitsubishi	0.38	0.32	0.38	0.48	0.38	0.38	0.38	0.38	0.39	0.38
Nihon	0.30	0.33	0.30	0.30	0.42	0.30	0.30	0.31	0.31	0.31
Onoda	0.20	0.27	0.20	0.20	0.20	0.29	0.20	0.20	0.20	0.20
Nippon Steel Chem.	0.42	0.46	0.42	0.42	0.42	0.42	0.60	0.42	0.43	0.43
Sumitomo	0.25	0.36	0.25	0.25	0.25	0.25	0.25	0.40	0.26	0.26
Tokuyama	0.26	0.30	0.26	0.26	0.26	0.26	0.26	0.27	0.37	0.26
Ube	0.24	0.28	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.32

(3) $\eta = 0.3$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.40	0.43	0.54	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Mitsubishi	0.39	0.32	0.39	0.48	0.39	0.39	0.39	0.39	0.39	0.39
Nihon	0.32	0.33	0.31	0.31	0.41	0.31	0.31	0.31	0.31	0.31
Onoda	0.22	0.27	0.22	0.22	0.22	0.30	0.22	0.22	0.22	0.22
Nippon Steel Chem.	0.42	0.46	0.42	0.42	0.42	0.42	0.57	0.42	0.42	0.42
Sumitomo	0.26	0.36	0.26	0.26	0.26	0.26	0.26	0.39	0.26	0.26
Tokuyama	0.28	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.37	0.28
Ube	0.26	0.28	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.34

(4) $\eta = 0.4$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.40	0.43	0.56	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Mitsubishi	0.41	0.32	0.41	0.50	0.41	0.41	0.41	0.41	0.41	0.41
Nihon	0.33	0.32	0.33	0.33	0.44	0.33	0.33	0.33	0.33	0.33
Onoda	0.23	0.27	0.23	0.23	0.23	0.32	0.23	0.23	0.23	0.23
Nippon Steel Chem.	0.43	0.46	0.43	0.43	0.43	0.43	0.59	0.43	0.43	0.43
Sumitomo	0.27	0.36	0.27	0.27	0.27	0.27	0.27	0.41	0.27	0.27
Tokuyama	0.30	0.29	0.30	0.30	0.30	0.30	0.30	0.30	0.40	0.30
Ube	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.36

(5) $\eta = 1$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.43	0.43	0.64	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Mitsubishi	0.48	0.30	0.48	0.60	0.48	0.48	0.48	0.48	0.48	0.48
Nihon	0.40	0.31	0.40	0.40	0.55	0.40	0.40	0.40	0.40	0.40
Onoda	0.31	0.26	0.31	0.31	0.31	0.43	0.31	0.31	0.31	0.31
Nippon Steel Chem.	0.45	0.45	0.45	0.45	0.45	0.45	0.67	0.45	0.45	0.45
Sumitomo	0.30	0.35	0.30	0.30	0.30	0.30	0.30	0.51	0.30	0.30
Tokuyama	0.39	0.28	0.39	0.39	0.39	0.39	0.39	0.39	0.52	0.39
Ube	0.38	0.27	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.49

Table 6: The Effects of Internal Frictions on Marginal Cost Estimation

μ denotes the extent of internalization. $\kappa(\varsigma_{d^i mpt}) = 1 - (1 - \varsigma_{d^i pmt})^2$ is used as the input pricing rule. Cartel-Time is cartel-time fixed effects. Cartel-Time-Share1984 is interaction terms between time fixed effects (during the cartel) and (the logarithm of) firm's market share in 1984.

	(1) $\mu = 1$	(2) $\mu = 0.9$	(3) $\mu = 0.8$	(4) $\mu = 0.7$	(5) $\mu = 0.6$	(6) $\mu = 0.5$
No. SS	-360.067	-364.885	-369.792	-374.699	-379.606	-384.513
	(57.163)	(56.693)	(56.266)	(55.857)	(55.467)	(55.096)
Productivity	-61.408	-60.253	-61.552	-62.852	-64.151	-65.451
	(317.118)	(314.508)	(312.139)	(309.872)	(307.708)	(305.651)
Gasoline Price	-58.681	-57.341	-56.502	-55.662	-54.823	-53.984
	(34.054)	(33.773)	(33.519)	(33.275)	(33.043)	(32.822)
Coal Price	-0.150	-0.147	-0.145	-0.142	-0.140	-0.137
	(0.189)	(0.188)	(0.186)	(0.185)	(0.184)	(0.183)
Fuel Oil Price	0.103	0.103	0.102	0.102	0.102	0.101
	(0.048)	(0.047)	(0.047)	(0.047)	(0.046)	(0.046)
Cartel-1985	2604.114	2590.710	2573.131	2555.553	2537.974	2520.395
	(944.723)	(936.947)	(929.890)	(923.136)	(916.691)	(910.563)
Cartel-1986	2423.465	2423.380	2422.826	2422.272	2421.718	2421.164
	(671.261)	(665.736)	(660.721)	(655.922)	(651.343)	(646.989)
Cartel-1987	3085.852	3087.467	3089.555	3091.643	3093.731	3095.819
	(594.437)	(589.544)	(585.104)	(580.854)	(576.799)	(572.943)
Cartel-1988	1969.532	1977.576	1982.990	1988.404	1993.818	1999.232
	(611.083)	(606.053)	(601.488)	(597.119)	(592.951)	(588.987)
Cartel-1989	1450.717	1449.406	1447.858	1446.310	1444.762	1443.214
	(660.745)	(655.307)	(650.371)	(645.647)	(641.140)	(636.854)
Cartel-1990	1131.344	1121.172	1112.720	1104.269	1095.817	1087.366
	(629.223)	(624.043)	(619.343)	(614.845)	(610.552)	(606.471)
Cartel-Time-Share1984			Yes			
R2	0.895	0.895	0.896	0.897	0.897	0.898
No. Obs			288			

Table 7: The Effects of Internal Frictions on The Critical Discount Factor

(1) $\mu = 1$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.37	0.45	0.50	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Mitsubishi	0.36	0.34	0.35	0.43	0.35	0.35	0.35	0.35	0.35	0.35
Nihon	0.28	0.35	0.28	0.28	0.36	0.28	0.28	0.28	0.28	0.28
Onoda	0.17	0.29	0.17	0.17	0.17	0.23	0.17	0.17	0.17	0.17
Nippon Steel Chem.	0.39	0.47	0.39	0.39	0.39	0.39	0.52	0.39	0.39	0.39
Sumitomo	0.22	0.37	0.22	0.22	0.22	0.22	0.22	0.31	0.22	0.22
Tokuyama	0.23	0.32	0.23	0.23	0.23	0.23	0.23	0.23	0.30	0.23
Ube	0.20	0.30	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.26

(2) $\mu = 0.9$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.37	0.45	0.48	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Mitsubishi	0.34	0.34	0.34	0.41	0.34	0.34	0.34	0.34	0.34	0.34
Nihon	0.27	0.35	0.27	0.27	0.35	0.27	0.27	0.27	0.27	0.27
Onoda	0.16	0.29	0.16	0.15	0.16	0.21	0.16	0.15	0.15	0.15
Nippon Steel Chem.	0.39	0.47	0.39	0.39	0.39	0.39	0.51	0.39	0.39	0.39
Sumitomo	0.21	0.37	0.21	0.21	0.21	0.21	0.21	0.30	0.21	0.21
Tokuyama	0.22	0.32	0.22	0.22	0.22	0.22	0.22	0.22	0.28	0.22
Ube	0.19	0.30	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.25

(3) $\mu = 0.8$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.36	0.44	0.47	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Mitsubishi	0.33	0.34	0.33	0.39	0.33	0.33	0.33	0.33	0.33	0.33
Nihon	0.26	0.35	0.26	0.26	0.33	0.26	0.26	0.26	0.26	0.26
Onoda	0.15	0.29	0.14	0.14	0.14	0.20	0.14	0.14	0.14	0.14
Nippon Steel Chem.	0.38	0.46	0.38	0.38	0.38	0.38	0.49	0.38	0.38	0.38
Sumitomo	0.21	0.37	0.21	0.21	0.21	0.21	0.21	0.29	0.21	0.21
Tokuyama	0.21	0.32	0.21	0.21	0.21	0.21	0.21	0.21	0.27	0.21
Ube	0.18	0.30	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.23

(4) $\mu = 0.7$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.36	0.44	0.45	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Mitsubishi	0.31	0.34	0.31	0.37	0.31	0.31	0.31	0.31	0.31	0.31
Nihon	0.25	0.35	0.25	0.25	0.31	0.25	0.25	0.25	0.25	0.25
Onoda	0.13	0.29	0.13	0.13	0.13	0.18	0.13	0.13	0.13	0.13
Nippon Steel Chem.	0.38	0.46	0.38	0.38	0.38	0.38	0.48	0.38	0.38	0.38
Sumitomo	0.21	0.37	0.21	0.21	0.21	0.21	0.21	0.28	0.21	0.21
Tokuyama	0.20	0.32	0.20	0.20	0.20	0.20	0.20	0.20	0.25	0.20
Ube	0.17	0.30	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.21

(5) $\mu = 0.6$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.36	0.44	0.44	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Mitsubishi	0.30	0.35	0.30	0.35	0.30	0.30	0.30	0.30	0.30	0.30
Nihon	0.24	0.35	0.24	0.24	0.29	0.24	0.24	0.24	0.24	0.24
Onoda	0.12	0.29	0.12	0.12	0.12	0.16	0.12	0.12	0.12	0.12
Nippon Steel Chem.	0.38	0.46	0.38	0.38	0.38	0.38	0.46	0.38	0.38	0.38
Sumitomo	0.21	0.37	0.20	0.20	0.20	0.20	0.20	0.26	0.20	0.20
Tokuyama	0.19	0.32	0.19	0.19	0.19	0.18	0.19	0.19	0.23	0.19
Ube	0.16	0.30	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20

(6) $\mu = 0.5$

	VI	No VI	Hypothetical Merger							
			Aso	Mitsubishi	Nihon	Onoda	Nippon Steel Chem.	Sumitomo	Tokuyama	Ube
Aso	0.35	0.44	0.42	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Mitsubishi	0.28	0.35	0.28	0.33	0.28	0.28	0.28	0.28	0.28	0.28
Nihon	0.23	0.35	0.23	0.23	0.27	0.23	0.23	0.23	0.23	0.23
Onoda	0.11	0.29	0.11	0.11	0.11	0.14	0.11	0.11	0.11	0.11
Nippon Steel Chem.	0.37	0.45	0.37	0.37	0.37	0.37	0.45	0.37	0.37	0.37
Sumitomo	0.20	0.37	0.20	0.20	0.20	0.20	0.20	0.25	0.20	0.20
Tokuyama	0.18	0.32	0.17	0.17	0.17	0.17	0.17	0.17	0.21	0.17
Ube	0.14	0.30	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.18