How Does Vertical Integration Affect Incentive to Collude? A Study of Upstream Collusion in Vertically Related Markets.

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Abstract

The possibility that vertical integration facilitates collusion has been an antitrust concern. However, such coordinated effect has not been well examined. This paper studies the relationship between vertical integration and upstream collusion, using a cartel case in the Japanese cement industry. Firms' behavior during the cartel is described in a successive oligopoly model and, based on the model, the critical discount factors under the actual and counterfactual market structures are quantified. The counterfactual analyses show that vertical integration between cement and ready-mixed concrete firms facilitated cement firms' (upstream) collusion. The main driving force is the outlet effect that vertically integrated downstream firms exit from the input market and thus upstream firms' deviation profits are reduced.

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1 Introduction

Identifying factors facilitating (or hindering) collusion has been one of the main research objectives in the field of industrial organization (IO). In response to antitrust issues, theorists have studied how different market characteristics influence firms' incentive to collude and provided testable implications on firm conduct. Empirical researchers have tested such theoretical implications by using the real world data and checked the validities of theories in different industries and markets. The positive dialogue between theory and empirical sides in the literature has enables IO researchers to make the list of factors facilitating collusive conduct that is instrumental in competition policy decision makings.[1]

One of the main aims in competition policy is to avoid environments under which firms find it easier to coordinate their behavior. For instance, in evaluating a proposed merger, antitrust authorities need to examine whether or not, if the merger is admitted, the resulting market structure will become an environment facilitating firms to collude. In this evaluation process, the checklist of pro-collusive factors could help antitrust agencies to assess the coordinated effects that the proposed merger potentially brings into the industry (market). Conversely, from the academic point of view, antitrust issues are the drivers of their research and the literature has evolved in response to antitrust policy.

Although there have been fruitful interactions between the competition policy and academic worlds, still there are issues that antitrust authorities have been concerned about but the academic literature has not been paying enough attention to. The

[1] Representative factors facilitating collusion, which are widely accepted both theoretically and empirically, are the small number of firms, higher concentration, product homogeneity, firm symmetry, the stability of demand, multi-market contacts, cross-ownership, etc. See Motta (2004), Whinston (2006), and Marshall and Marx (2012) for a detailed discussion.

coordinated effect of vertical integration is one of such antitrust issues. The possibility that strengthening vertical relationship between upstream firms and downstream firms facilitates collusive behavior has been stated in antitrust agencies. For instance, in the Non-Horizontal Merger Guidelines, the Department of Justice in the U.S. states the concern on the coordinated effects that vertical integration brings. Similar statements can be seen in the non-horizontal merger guidelines of European Commission in EU, the Competition and Market Authority, and the Japan Fair Trade Commission.

Despite its importance, the coordinated effects of vertical integration has not been studied for a long time. That is, the academic has almost ignored the coordinated effects. In fact, the first (theoretical) work, which is provided by Nocke and White (2007), was published long after the antitrust authorities' concerns on the coordinated effects was first stated.[2] Unfortunately, the empirical literature is lagging behind further. To the best of my knowledge, no empirical work has been done to date.

The goal of the present paper is to empirically examine how vertical integration affects (upstream) firms' incentive to collude in vertically linked industries. To achieve this goal, a cartel case in the Japanese cement industry is studied. This collusion was formed by (upstream) cement firms in the Chugoku region. They initiated this cartel on July 1985 and lasted almost five years until they stopped in response to a cartel investigation into another cement market. Coupled with the cartel in the Hokkaido region that had been formed almost the same time period as that in the Chugoku region, the amount of fines levied on the cement firms involved was the largest ever in the Japanese antitrust history at that time.

Another important feature is that cement firms own (at least partially) downstream ready-mixed concrete firms. This feature of the cement and ready-mixed concrete

[2] The seminal work of Nocke and White (2007) is followed by Normann (2009), Nocke and White (2011), and Biancini and Ettinger (2017).

industries provides a good opportunity to explore the effects of vertical integration on upstream firms' incentive to collude.

In order to explore the incentive to collude, the current study constructs and estimates a structural model. The model takes into account two features of the industries, collusion and vertical relationship. Collusive behavior of upstream firms is modeled by exploiting the fact revealed during the cartel litigation. As the results of cartel investigation by Japan's FTC (JFTC), the aims and rule of the cartel was revealed. In particular, the cartel jointly limited the total amount of supply every month in the region and allocates quotas to cartel member firms based on the share allocation . With this knowledge about how the cartel worked, firms described in the theoretical model as ones (strictly) capacity-constrained by regarding quotas (allocations) as capacities.

To deal with the vertical relationship between cement and ready-mixed concrete industries, the theoretical model in the current study uses the framework of successive oligopoly. Cement firms in the upstream chooses their supply quantities to cement markets, considering the derived demand for cement, which is realized as the result of ready-mix concrete firms' quantity setting decisions. The level of market supply affects (mainly) vertically unintegrated downstream firms' marginal costs and thus affects the equilibrium outcomes in the downstream industry. In the case of vertically integrated upstream firms, they consider this effect of market supply on independent downstream firms' costs and in turn their downstream ready-mix concrete firms' profits. These contradicting incentives are taken into account in the theoretical model and optimal behavior of vertically integrated (and unintegrated) upstream firms is described.[3]

Parameters in the theoretical model are estimated by using the data which spans

[3]Gaudet and Van Long (1996) first consider a situation where vertically integrated upstream downstream) firms can supply input to (buy input from) vertically unintegrated downstream (upstream) firms. On the other hand, Sallinger (1988) considers the setting where a vertically integrated firm stops supplying to market.

the period of the cartel and the period after it. The effect of the cartel appears in the form of shadow marginal cost in the marginal cost function of upstream firms because, in the model, each firm's quota plays exactly the same role as capacity. The main objective in the estimation stage is to estimate upstream firms' marginal cost and shadow costs. For this estimation, information about the period after the cartel being convicted is utilized. For three years after the cartel, 1991-1993, cement firms had to report their sales activity to the JFTC as one of the penalties. During this period, it is unlikely that cement firms have colluded and thus this period of the JFTC monitoring can be regarded as the benchmark period of competition in the cement industry. This fact can complement the cartel period data and help precisely estimate the marginal costs and shadow prices.

With estimates of demand and cost parameters in both upstream and downstream industries, incentive for upstream firms to collude is analyzed. For analyzing firms' incentive, the critical discount factor, which is the minimum discount factor needed to support collusion, is used as a criterion as does the textbook collusion theory. The critical discount factors are calculated under the (actual) market structure with vertical integration and counterfactual ones. The main result of counterfactual exercises in the current study is that the critical discount factor needed to sustain the actual level of collusion (in terms of the total amount of profits) under the actual market structure is less than that under the counterfactual environment where there is no vertical integration. This means that vertical integration increases incentive to collude.

The present paper has several features and provides new empirical findings. First and foremost, this paper is one of the first empirical studies of collusive incentive in vertically-related markets. Focusing on vertical integration, upstream firms' incentives to collude are empirically examined and the two opposing effects of vertical integration, which are identified in the theory literature, are measured. Second, closely related to the first feature, it can be considered that the present paper provides looks at the coordinated effects of merger from an angle distinct from previous studies. The coordinated effects of horizontal mergers has been studied both theoretically and empirically. Miller and Weinberg (2017) and Igami and Sugaya (2022) are representative papers recently published. The focus of the present paper is on the coordinated effects of vertical integration (merger) that has not been empirically studied. Third, this is one of the first empirical studies using the framework of successive oligopoly. Few empirical studies using this theoretical framework have been done to date. This situation is a little bit surprising, considering the fact that the literature that studies vertical relationship between firms with bargaining models has been growing considerably. For instance, Ho (2009), Lee and Ho (2017, 2019), and Crawford, Lee, Whinston, and Yulukoglu (2018) are representative studies using bargaining models. However, to the best of my knowledge, there are only handful studies using successive oligopoly models.

Cement and ready-mixed concrete industries have been used extensively for empirical studies by many researchers. For instance, the US cement and ready-mixed concrete industries are chosen as empirical laboratories in the studies of Jans and Rosenbaum (1996), Syverson (2004), Hortacsu and Syverson (2007), Ryan (2012), Collard-Wexler (2013, 2014), and Backus (2020). On the other hand, Roller and Steen (2006) study a cartel in the Norwegian cement industry and Salvo (2010) tests the conduct of a cartel in the Brazilian cement industry, and Nishiwaki and Kwon (2013), Nishiwaki (2016), and Okazaki, Onishi, and Wakamori (2022) examine possible (in)efficiencies caused by capacity divestment in the Japanese cement industry. In the present paper, the cartel case in the Chugoku region in Japan is utilized as an empirical laboratory fo the analysis of the relationship between vertical integration and collusion (or coordinated effect of vertical integration).

The rest of the paper is organized as follows. First, the cement cartel case in the Chugoku region in Japan is introduced. Secondly, the descriptions of the cement and ready-mixed concrete industries are provided. Then, the model that captures upstream firms' behavior during the cartel period is developed and it is estimated. Finally, the counterfactual exercises show the effects of vertical integration on upstream firms' cartel incentive.

2 The Cartel Case in the Chugoku Region 1985-1990

Firms in the cement industry formed an illegal cartel for several times during the 70s and 80s. Among these cartel, the cartels in the Chugoku and Hokkaido regions that were detected and convicted in 1990 were the biggest ones (in terms of fines). The sum of fines levied to firms involved in these cartels amounted to over 150 million yen and this amount was the largest amount than any other cartel in Japan's antitrust history at the time of being convicted.[4] This paper's focus is on one of these two cartels, the cartel in the Chugoku region.

The Chugoku region is the westernmost region of Japan's main island, Honshu. It consists of the following five prefectures, Hiroshima, Okayama, Shimane, Tottori and Yamaguchi. In this region, nine cement firms were operating: Aso Cement, Mitsubishi Cement, Mitsui Mining, Nihon Cement, Nippon Steel, Onoda Cement, Sumitomo Cement, Tokuyama, Ube. All of them were involved in the cartel and the cartel started on July 1985 and ended on April 1990 when the JFTC initiated their cartel investigation into the Hokkaido region, according to the official document of the JFTC.

[4]This cartel has the largest for over 15 years.

Local managers of nine cement firms in the Chugoku regions have held meeting monthly and discussed about the region's cement market. Two months before starting the cartel, managers reached an agreement regarding when to start, how to limit quantities supplied and raise prices and how to continue the cartel. The cartel scheme is as follows. The main control of cement firms was the supply quantity. They decided to limit the total supply. Local managers held a monthly meeting and set the target level by taking into account for the month's demand condition. Once the limit was set, each member firm was allocated quota. Quota was determined basically by the allocation rule that was agreed just before the cartel started. Thus, after the total quantity was determined at the meeting of local manages, each firm's quota was mechanically calcuated.

The allocation rule used by the cartel was a mix of allocation based on shares and fixed-amount adjustments for (some) firms. For instance, Aso was given 1,500 tonnage in addition to the amount based on its allocation share while, in Onoda's case, its quota was the share based amount (total supply times Onoda's share) minus 2,000 tonnage. The end result of this allocation rule is provided in Table **??**. The important thing to the current study is that by this allocation rule firms kept their shares that were realized before the cartel during the cartel period. As shown in Table **??**, although some small fluctuations within a firm overtime can be seen, the firm shares were almost unchanged before and during (and after) the collusion.

On April 1990, the JFTC started their cartel investigation into the Hokkaido market. In response to this investigation, firms in the Chugoku region held a meeting and decided to end the five-year cartel on April.[5] However, JFTC expanded their investigation to all cement markets in Japan and raided cement firms headquarters, plants,

[5]Three firms, Onoda, Mitsubishi, and Nihon, were involved in the cartel in Hokkaido.

distribution centers all over Japan. As the result of this nationwide cartel investigation, the cartel in the Chugoku was detected.

3 Local Markets in the Ready-Mixed Concrete Industry

Competition in the ready-mixed concrete industry in Japan is localized due to the delivery cost, as is that in many other countries such as the US and Europe. In addition, concrete producers need to finish the delivery of their products within one and half hours. This is one of the requirements by the Japan Industrial Standards (JIS), which plays the role of de facto regulation on the production, delivery, and other activities in the ready-mixed industry. [6]. Because of this nature of the product, within a single prefecture, smaller geographical areas should be considered local concrete markets.

The issue here is how to define local ready-mixed concrete markets. Defining local markets properly is always a challenge for empirical studies.

To define local competition taking place as precisely as possible, the present study relies on a governmental research organization, the construction research institute. This research institute was founded in 1955 as an organization of the Ministry of Land (currently, the Ministry of Land, Infrastructure, Transport and Tourism). The aim is to survey prices of almost all raw materials used in construction sectors, services and wages. These price information is published in the monthly magazine, Kensetsu Bukka.

For the ready-mix concrete industry, prices in geographically distinct cities and towns (within a prefecture) are surveyed to see how ready-mix concrete prices differ from one geographical market to another. This organization's approach of collecting

[6]JIS A 5308 defines the requirements that firms in the ready-mixed industry should satisfy to be certified by the JIS committee. Firms are given a certification, which is called the JIS mark, and can verify the conformity of their products to customers.

price information can be considered as a reflection of the fact that competition in the ready-mix concrete industry is (even) more localized than the cement industry where competition is also localized but in a prefectural level.

The construction research institute picks several main cities and towns in different geographical areas within a single prefecture. These cities and towns are typically the largest cities or towns in these areas (in terms of population). Considering that the magazine's aim is to provide its subscribers useful information on the ready-mix concrete industry, it is expected that cities and towns are selected to represent local ready-mix concrete markets within a prefecture and to inform subscribers how prices are different from one local market to another. Therefore, it is natural to take advantage of the magazine's approach of surveying price information for defining ready-mix concrete markets.

One issue is that the number of cities and towns that the organization surveyed ready-mix concrete prices was increased in the 1980s. As the result of the expansion of cities and towns, in the Chugoku region, 10 cities and 3 towns were newly added to the magazine, and 31 cities and towns were surveyed in April 1990. During the 1990s, however, no cities and towns were added.[7] This implies that 21 cities and 1 towns which were selected by 1991 are considered sufficient to capture price differences in the ready-mix concrete industry. Therefore, this study uses these cities and towns as a basis to form ready-mix concrete markets.

A ready-mix concrete market is defined in the following way, as a collection of cities and towns. First, for a city (town) where ready-mix prices are surveyed, a circle with 20 kilometer radius around it is created. Then, cities and towns, which are within 20 kilometer straight-line distance, are chosen to constitute the local ready-mix concrete

[7]During the 2000s, many municipalities experienced mergers because the Japanese government promoted municipal mergers. Due to these mergers, cities and towns which are surveyed are changed.

market. If there are cities and towns which are within more than one circle, they are included to the circle of the nearest city (or town) surveyed.

For instance, in Hiroshima prefecture, six cities and one town are selected to survey ready-mix concrete prices in 1991. Based on these cities and towns, 7 local ready-mix concrete markets are defined. Regarding ready-mix concrete price, information provided by the construction price research organization could be used. However, one issue is that cities and towns surveyed were continuously expanded during the 1980s. This process was completed in 1991. As the result, about half of cities and towns that were surveyed in 1991 and after were not surveyed before 1991. Therefore, during the cartel period, 1985-1990, many cities not surveyed and there are no observations.

Therefore, information obtained from (the magazine of) the CRI is used for only defining ready-mix concrete markets. Price information is obtained from another data source, the census of manufacture. Using establishment level revenue and quantity data, the average ready-mix concrete prices are calculated. For instance, for a ready-mix concrete market, revenues and quantities of not all but several concrete plants are observed. Using these information, the average ready-mix price in this market is calculated and this average price is regarded as the ready-mix concrete price in this market.

4 Vertical Relation in the Cement and Concrete Industries

The vast majority of cement is consumed in the ready-mix concrete industry. A ready-mix concrete firms are very small in terms of the number of workers. The average number is less than eight workers per plant. Given the fact that the plant-firm ratio is 1.12, they are very small and the vast majority of them are single-plant firms. On the other hand, the numbers of firms and plants are very large, compared with that of cement firms. Table presents

Another important feature of the ready-mixed concrete industry is its vertical relationship with the cement industry. Forward integration by cement firms can be seen in the cement and ready-mix concrete industries. That is, ready-mixed concrete (downstream) firms are vertically integrated by cement (upstream) firms. Table shows that vertical integration in the Chugoku region. Overall, about 25% of ready-mixed concrete firms are vertically related with upstream cement firms. The important feature about this cement-concrete vertical integration is that most of vertically integrated ready-mixed concrete firms are not 100% owned by cement firms. Only 10% of vertically integrated firms are 100% merged by upstream firms. The rest of vertically integrated firms is partially owned. Firms that are 50% or more owned are bout 20% of vertically integrated firm while about 70% are less than (or equal to) 50% owned.

For upstream firms, the degree of vertical integration varies from firm to firm as presented in Table. Larger firms own more ready-mixed concrete firms. Onoda, Tokuyama, Ube and Nihon Cement are the largest four firms in the region (in terms of market share). The number of ready-mixed concrete firms of these four upstream firms amounts to 88, which is over 80% of total vertically integrated firms. Ready-mixed concrete firms which are 100% owned are very rare for every cement firms (except Mitsubishi cement). The overall pattern of vertical integration is kept for each cement firm. On the other hand, Nippon Steel and Sumitomo cement do not have vertical relationship with downstream firms.[8]

[8]The presence of these unintegrated firms provides an important information. The reason is that, due to the lack of information on downstream firms supply quantity, integrated firms total supply cannot be divided into . On the other hand, this data issue does not arise to unintegrated firms. Therefore the presence will help precisely estimate parameters of the model, specifically those in the marginal cost function.

5 Model

In this section, a theoretical model describing firms' behavior in the cement and ready-mixed concrete markets is constructed. The model is based on the framework of successive oligopoly with vertical integration (mergers), which are developed by Greenhut and Ohta (1979) and Salinger (1988). However, one distinct feature in the cement and ready-mixed concrete markets is that integrated upstream firms supply both their own downstream affiliates and independent downstream firms. In other words, integrated cement firms do not exclusively supply cement to their own integrated downstream firms. This situation is a clear contrast to the models of Greenhut and Ohta (1979) and Salinger (1988) where, once vertical integration between a upstream firm and a downstream firm occurs, the vertically integrated upstream firm becomes the exclusive input supplier to the integrated downstream firm and stops supplying to other independent downstream firms and exits from the input market.For this reason, a modification to these seminal models is needed to explain firms' behavior in the context of the Japanese cement and ready-mixed concrete markets.

Gaudet and Van Long (1996) develop a successive oligopoly model that handles the situation where vertically integrated upstream firms are allowed to supply inputs to independent downstream firms as well as their own downstream firms. More precisely, upstream firms endogenously choose how much they supply to the input market (and independent firms buy inputs externally at the market price).[9] Because of this flexibility, their model is more suitable to explain firm behavior in the cement and ready-mixed concrete industries.

[9]Gaudet and Van Long (1996) consider a situation where a vertically integrated downstream firm can buy inputs from its integrated upstream firm and other unintegrated upstream firms in the input market. The main motive for integrated downstream firms is to raise rivals's (marginal) cost by buying (a large amount of) inputs and raising the input price. However, this aspect of their model is not relevant to the present study because vertically integrated ready-mixed concrete firms are only supplied by their cement firms.

Another feature to capture in the model, which is the most important feature to the present study, is collusion among upstream firms so that the successive oligopoly model should take into account the fact that upstream firms colluded. How to describe firms' collusive behavior is a challenging task in general. Fortunately, for the present study of the cement cartel of interest, the facts revealed during the prosecution process can be leveraged to model their illegal cooperative behavior. The cartel behavior is modeled as capacity-constrained profit maximizing. Quotas decided on the cartel's allocation rule serve as capacity of each upstream firm and then they make supply decisions under the constraints. The effects of the cartel allocation rule appears as shadow marginal costs in the model and the shadow costs represents the amount of burden that each firm bears to sustain the realized collusion in monetary term. This modeling strategy is basically the same as that employed in Goldberg (1995) and Berry, Levinsohn, and Pakes (1999) where they model VER imposed on Japanese automakers in the 1980s as capacity constraint (although they use the approach to capture completely different from the present study).

In the subsections that follows, first collusive behavior in the upstream industry is introduced as constrained profit maximizing behavior and then components of profits that upstream firms obtain are described in detail.

5.1 Upstream Collusion

First, before going into the details of successive oligopoly. The collusive behavior of upstream firms is built on the following assumptions based on the following facts that the JFTC's cartel investigation reveals.

First, the cartel that all cement firms operating in the Chugoku region joined was initiated at 1985 and had lasted until firms stopped colluding on their own Managers met every month to decide the monthly The cartel was given up after the cartel investigation into the Hokkaido market started. From this fact, the cartel never broke down.

Second, the cartel's aim was to control the total amount of cement supply in the region to raise prices. To achieve this goal, cement firms were given (monthly) quotas based on the allocation rule that is basically based on the market shares realized just before the cartel was initiated. Because the cartel did not broke down on its own, cement firms complied with this allocation rule and did not supply the amount exceeding their quotas (although there might be some top-ups to avoid the cartel from collapsing). This means that quotas served as strict capacity constraints beyond which cement firms cannot supply. [10]

Third, another feature of the allocation rule is that a quota decided the amount that each cement firm is allowed to supply in the region but it did not restricted the amount in each prefecture. Alternatively, as long as firms keep their quotas, they could freely choose which prefecture to supply (although all firms ended up supplying to all prefectures) and how much to supply in each prefecture.

Considering these facts, it is reasonable to assume that, after the total supply is set by the cartel committee and then quotas are determined, each cement firm's objective is to maximize its profit by choosing quantities supplied in prefectures, given other cement firms comply with the cartel rule and maximize their profits in the same way. Formally, cement firm is' profit maximization problem becomes as the following.

$$\max_{q_i^{nv}, q_i^{v}} \sum_{p=1}^{P} \Pi_{ip}$$
$$s.t. \;\; \bar{q}_i \geq \sum_{p=1}^{P} \left(q_{ip}^{nv} + q_{ip}^{v} \right) \tag{1}$$

[10] Modeling cartel behavior in this way is very similar to the approach employed in modeling VER by Japanese car makers in Goldberg (1995) and Berry, Pakes, and Levinsohn (1995). In their analyses, Japanese car makers are constrained by their quotas, which were determined by the MITI (currently the METI). The effect of these quotas are reflected as shadow marginal costs in the marginal costs.

$R_i(Q) = \bar{q}_i$ where $q_i^{nv} = (q_{i1}^{nv}, \ldots, q_{iP}^{nv})$ are quantities supplied to prefectural input (cement) markets and $q_i^v = (q_{i1}^v, \ldots, q_{iP}^v)$ represents quantities supplied to firm i's vertically integrated ready-mixed concrete firms ($P = 5$). The profit of cement firm i in the Chugoku region is the sum of profits obtained in five prefectures, that is, $\Pi_{i1}, \ldots, \Pi_{i5}$. $\bar{q}_i$ is i's quota and the sum of q_i^{nv} and q_i^v is i's total cement supply in the region. The sum of quantities to input markets and those to own downstream firms is subject to quota provided to firm i by the cartel allocation rule because the allocation rule restricts only the regional level of supply of each not the prefectural supply of the firm.

Upstream firm i's profit in prefecture p consists of three different profits: Profit gained from the prefectural input market, profit gained from internal transactions, and the sum of profits of downstream ready-mixed concrete firms (if cement firm i vertically integrates downstream firms). The profit of cement firm i is defined as

$$\Pi_{ip} = \underbrace{\sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} \varsigma_{d^imp} \pi_{d^imp}}_{\text{Downstream firms' profits}} + \underbrace{\sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} (W_{d^imp} - c_{ip}^U) q_{d^imp}^v}_{\text{Selling to Own downstream firms}} + \underbrace{(W_p - c_{ip}^U) q_{ip}^{nv}}_{\text{Selling to market}}. \quad (2)$$

The first term is the sum of profits of downstream firms that upstream firm i owns. π_{d^imp} indicates the profit of downstream firm d^i which is operating in ready-mixed market m in prefecture p and ς_{d^imp} indicates upstream firm i's stake in downstream firm d^i ($0 < \varsigma_{d^imp} \leq 1$). N_{imp}^D in the number of ready-mixed concrete firms that firm i fully or partially owns at ready-mixed market m within prefecture p. M_p is the number of ready-mixed concrete markets in prefecture p.

The second term is profit obtained by selling cement to vertically integrated downstream firms. W_{d^imp} indicates the transaction price at which integrated downstream firm d^i is supplied by upstream firm i internally. $q_{d^imp}^v$ indicates the amount of cement that is supplied to d^i. In other words, $q_{d^imp}^v$ is also the amount of cement that d^i

demands upstream firm i to produce the amount of ready-mixed concrete s_{d^imp}.

The last component is the profit obtained in the prefectural input market. W_p is the market price of cement and q_{ip}^{nv} is the supply quantity of upstream firm i to supplied to independent downstream firms. c_{ip}^U is the (marginal) cost of cement firm i and it is assumed constant across ready-mixed concrete markets within the same prefecture p.

The upstream firm i's constrained profit maximization problem is expressed as the following Lagrangean:

$$\begin{aligned} L(q_{ip}^v, q_{ip}^{nv}, \lambda_i) &= \sum_{p=1}^{P} \left\{ \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} \left\{ \varsigma_{d^imp} \pi_{d^imp}^D + (W_{d^imp} - c_{ip}^U) q_{d^imp}^v \right\} + (W_p - c_{ip}^U) q_{ip}^{nv} \right\} \\ &\quad + \lambda_i (\bar{q}_i - \sum_{p=1}^{P} \left(q_{ip}^{nv} + q_{ip}^v \right)) \\ &= \sum_{p=1}^{P} \left\{ \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} \left\{ \varsigma_{d^imp} \pi_{d^imp}^D + (W_{d^imp} - c_{ip}^{U,\lambda}) q_{d^imp}^v \right\} + (W_p - c_{ip}^{U,\lambda}) q_{ip}^{nv} \right\} \\ &\quad + \lambda_i \bar{q}_i \quad (3) \end{aligned}$$

where $c_{ip}^{U,\lambda} = c_{ip}^U + \lambda_i$ and $q_{ip}^{nv} = \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} q_{d^imp}^{nv}$. The important parameter here is λ_i that represents the shadow marginal cost of firm i that arises from the allocation rule of the cartel. As in (3), the shadow marginal cost serves an additional marginal cost to the physical marginal cost of firm i, c_{ip}^U, when firm i decides q_i^v and q_i^{nv}, and reduces these optimal quantities to the target level that the cartel designates.[11]

The profits of downstream firms, π_{d^imp}, depend on cement prices. Market prices influence independent ready-mixed concrete firms' (marginal) costs and then, as the result of downstream market competition, vertically integrated concrete firms' profits are affected by cement prices. Therefore, to determine the optimal behavior of upstream cement firm i, the downstream firms' profit functions need to be defined in detail in

[11]It is assumed that all cement firms' capacity constraints are binding. Because this is an all inclusive cartel firms involved always have an temptation to supply more than quotas allocated during collusion.

the next subsection.

5.2 Downstream Markets

The main downstream firms are ready-mixed concrete firms. In this subsection, first, vertically integrated and unintegrated concrete firms' profit functions are defined. Then, equilibrium outcomes in local ready-mixed concrete markets in prefectures are defined and the demand functions for cement are derived as the result of the downstream competition. In addition to the main downstream industry, there are other industries that use cement as an input for their production. These industries also constitute demand for cement. The total demand is derived as the sum of demand from the ready-mixed concrete firms and that from the rest of industries that use cement as an input these.

5.2.1 Ready-Mixed Concrete Firms' Profit

Competition in the ready-mixed concrete industry is more localized than that in the cement industry where a prefecture is defined as one market. Therefore, even within a single prefecture, there are some local ready-mixed concrete markets, as explained in the section of the industry description. Let mp denote market m in prefecture p.

In a local ready-mixed concrete market, there are two types of ready-mixed concrete firms, independent concrete firms, which has no vertical relationship with any upstream cement and vertically integrated firms, which are owned fully or partially (less than 100%) by an upstream cement firm.

Independent Concrete Firms The profit of unintegrated downstream firms is defined. Let d^0 indicate that this downstream firm d has no vertical relationship with any upstream firm (although, of course, this firm is supplied by one or some of upstream firms).

$$\pi^D_{d^0mp} \;=\; \left(P_{mp} - c^D_{d^0mp}\right) s_{d^0mp} = \left(P_{mp} - \tilde{c}^D_{d^0mp} - \tau W_p\right) s_{d^0mp} \tag{4}$$

The only difference between integrated and unintegrated firms' profit functions is that the unintegrated firm d^0 is supplied at the market price W_p. $\tilde{c}^D_{d^0mp}$ is a composite of d^0's all marginal costs except W_p. The marginal cost is further divided into the input price, W_p, which is the cement price at which firm d^0 buys and $\tilde{c}^D_{d^0p}$ is the composite of costs of buying inputs other than cement, for instance, water, gravel, sand among others, and other operational costs including costs in the production and delivery of ready-mixed concrete. τ indicates the cement-concrete ratio in the production process. To produce one unit of ready-mixed concrete (m^3), around 0.3 tonnage cement is used.[12] The inverse demand curve is assumed to be the following linear form,

$$P_{mp} = a_{mp} - bS_{mp} \tag{5}$$

where a_{mp} is the demand shifter and b is the slope of the demand curve.

Vertically Integrated Concrete Firms A downstream ready-mixed concrete firm which has a vertical relationship with upstream firm i is indicated by d^i. Downstream firm d^i's profit is expressed in the following manner.

$$\pi^D_{d^imp} \;=\; (P_{mp} - c^D_{d^imp})s_{d^imp} = (P_{mp} - \tilde{c}^D_{d^imp} - \tau W_{d^imp})s_{d^imp} \tag{6}$$

where P_{mp} is ready-mix concrete price in local market m in prefecture p and $c^D_{d^imp}$ is the marginal cost of concrete firm d^i. s_{d^imp} is quantity supplied by d^i. The marginal cost consists of W_{d^imp}, which is the cement price at which firm d^i is supplied and $\tilde{c}^D_{d^ip}$ is the composite of other costs of buying other inputs and costs in the production and delivery stages.

[12]In the present paper, fixed-proportions technology is assumed as in other empirical studies on cement and concrete markets, such as Hortaçsu and Syverson (2007).

Unlike a typical situation studied in the theoretical literature on vertical integration, one distinctive feature of the cement and concrete firm vertical relationship is that the vast majority of integrated concrete firms is not fully but partially owned by cement firms. If concrete firms are fully integrated by upstream firms, it is reasonable to assume that the input price, W_{d^imp}, is the marginal cost of upstream firm i, c^U_{ip}, as assumed in theoretical models in the literature, such as Salinger (1988) and Gaudet and Van Long (1996). Unfortunately, this 100% vertical integration is rare in the context of vertical integration in the cement and concrete industries and thus the relationship between ownership structure and input price need to be introduced into the model. However, even in the case of partial integration, it is still reasonable to assume that a vertically integrated downstream firm d^i's input price depends on the the extent of vertical integration of d^i, that is, ς_{d^imp}. Therefore, in the present study, it is assumed that input price, W_{d^imp}, is represented by a function of ς_{d^imp}. A unfortunate thing, due to the data limitation, is that input prices are not observed and it is impossible to estimate the input price function due to this data limitation.

To deal with the above issues arising from partial vertical integration and lack of input price data, several scenarios about how cement input prices are determined are considered. Different scenarios are expressed in a consistent manner by the following pricing rule which relates upstream firm i's stake in d^i, ς_{d^imp}, with input price of its downstream firm W_{d^imp}.

$$W_{d^imp} = \kappa_{d^imp} c^U_{ip} + (1 - \kappa_{d^imp}) W_p, \quad \kappa_{d^imp} \in (0, 1] \tag{7}$$

where $\kappa_{d^imp} = \kappa(\varsigma_{d^imp})$ is a function which depends on ς_{d^imp}. The basic idea of this pricing rule is, as mentioned above, that W_{d^imp} is determined based on ς_{d^imp},and it is settled on somewhere between c^U_{ip} and W_p.[13]

[13] W_{d^imp} cannot be above W_p because, if it can, d^i must choose externally buying cement from the

The function $\kappa(\varsigma_{d^imp})$ serves as the device of expressing different input pricing scenarios. For instance, when κ^i_{dp} is set ς_{d^imp}, that is, $\kappa^i_{dp} = \varsigma_{d^imp}$, W_{d^imp} is proportional to the extent of vertical integration of firm d^i. When firm d^i is fully owned by firm i, it is supplied at firm i's marginal cost. For other cases, as upstream firm's stake, ς_{d^imp} increases, W_{d^imp} decreases accordingly. Alternatively, another specification might be that 50% or more integrated firms are supplied at upstream firms' marginal costs while the rest of downstream firms are supplied at market price W_p. This scenario is expressed by setting $\kappa(\varsigma_{d^imp}) = 1$ if $\varsigma_{d^imp} \geq 0.5$ and $\kappa(\varsigma_{d^imp}) = 0$ otherwise.

In the present paper's analysis, $\kappa^i_{dp} = \varsigma_{d^imp}$ is treated as the benchmark case while other scenarios are examined to check whether different specifications on the input pricing rule affect the empirical results or not.

5.2.2 Equilibrium Outcome and Derived Demand

The profits of downstream firms are realized as the result of competition in local ready-mixed concrete markets. At the same time, the demand for input (cement) is derived as a function of equilibrium concept, downstream demand and supply conditions.

In order to determine these downstream firms' profits, how downstream firms interact is needed. One concerning factor about modeling competition in the ready-mix concrete industry is that the industry is one of the industries which can apply for an antitrust exemption and form a union that coordinates its member firms' sales activities including arranging the delivery of ready-mixed concrete. Typically, firms belonging in such a union are likely to refrain from competing each other.

Although there is a challenge to describe how ready-mixed firms behaves, for the time being, it is assumed that firm compete in quantity, and market outcomes are realized as a Cournot equilibrium. With this equilibrium concept, the equilibrium

input market.

outcomes are The equilibrium supply quantity of vertically integrated downstream firm d^i derived as done usual in the setting of heterogeneous firms quantity competition and becomes the following form.

$$\begin{aligned} s_{d^imp} &= \frac{1}{(N^D_{mp}+1)b}\Bigg(a_{mp}-(N^D_{mp}+1)\left(\tilde{c}^D_{d^imp}+\tau\left\{\kappa_{d^imp}c^U_{ip}+(1-\kappa_{d^imp})W_p\right\}\right) \\ &\quad +\sum_{j=0}^{N^U}\sum_{d^j=1}^{N^D_{jmp}}\left(\tilde{c}^D_{d^jmp}+\tau\left\{\kappa^j_{dmp}c^U_{jp}+(1-\kappa^j_{dmp})W_p\right\}\right)\Bigg) \\ &= \frac{1}{(N^D_{mp}+1)b}\Bigg(a_{mp}-(N^D_{mp}+1)\left(\tilde{c}^D_{d^imp}+\tau\kappa_{d^imp}c^U_{ip}\right) \\ &\quad +\sum_{j=0}^{N^U}\sum_{d^j=1}^{N^D_{jmp}}(\tilde{c}^D_{d^jmp}+\tau\kappa^j_{dmp}c^U_j)+\Big((N^D_{mp}+1)\kappa_{d^imp}-(1+\sum_{j=0}^{N^U}\sum_{d^j=1}^{N^D_{jmp}}\kappa^j_{dmp})\Big)\tau W_p\Bigg) \\ &= \frac{1}{(N^D_{mp}+1)b}\Bigg(a_{mp}-(N^D_{mp}+1)\left(\tilde{c}^D_{d^imp}+\tau\kappa_{d^imp}c^U_i\right) \\ &\qquad +\tilde{c}^D_{mp}+\tau\kappa c^U_{mp}+\Big((N^D_{mp}+1)\kappa_{d^imp}-(1+\kappa_{mp})\Big)\tau W_p\Bigg) \end{aligned} \tag{8}$$

where $\tilde{c}^D_{mp}=\sum_{j=0}^{N^U}\sum_{d^j=1}^{N^D_{jmp}}\tilde{c}^D_{d^jmp}$ and $\tau\kappa c^U_{mp}=\sum_{j=0}^{N^U}\sum_{d^j=1}^{N^D_{jmp}}\tau\kappa^j_{dmp}c^U_j$. Similarly, the equilibrium supply of a non-integrated downstream firm becomes

$$s_{d^0mp} = \frac{a_{mp}-(N^D_{mp}+1)\tilde{c}^D_{d^0mp}+\tilde{c}^D_{mp}+\tau\kappa c^U_{mp}-(1+\kappa_{mp})\tau W_p}{(N^D_{mp}+1)b}. \tag{9}$$

Notice that the unintegrated firm's $\kappa^i_{d^0p}=0$ and this firm is supplied cement at the prefectural (cement) market price W_p.

Next, by aggregating unintegrated firms' supply quantities, the following (market) demand function for cement is obtained. Integrated firms are supplied the necessary amount of cement by their integrated upstream (cement) firms. On the other hand, unintegrated downstream firms need to buy the amount of input at the (prefectural) cement market in order to supply their equilibrium quantity. The total amount of the equilibrium quantities of unintegrated firms consists of the market demand for cement.

The aggregation of equilibrium supply quantities leads to the following form.

$$S_{mp}^{0} = \frac{N_{mp}^{D,0}(a_{mp} + \tilde{c}_{mp}^{D} + \tau\kappa c_{mp}^{U}) - (N_{mp}^{D} + 1)\tilde{c}_{p}^{D,0}}{(N_{mp}^{D} + 1)b} - \frac{N_{mp}^{D,0}(1 + \kappa_{mp})}{(N_{mp}^{D} + 1)b}\tau W_{p} \quad (10)$$

where $N_{mp}^{D,0}$ indicate the number unintegrated concrete firms in local market m and $\tilde{c}_{p}^{D,0}$ is the sum of cement price subtracted marginal costs of unintegrated firms, $\tilde{c}_{p}^{D,0} = \sum_{d^0=1}^{N_{jmp}^{D}} \tilde{c}_{d^0 mp}^{D}$.

The amount of cement that unintegrated firms in m demand is derived by multiplying S_{mp}^{0} with the cement-concrete ratio, τ.

$$\begin{aligned} Q_{mp}^{nv} &= \tau\left(\frac{N_{mp}^{D,0}(a_{mp} + \tilde{c}_{mp}^{D} + \tau\kappa c_{mp}^{U}) - (N_{mp}^{D} + 1)\tilde{c}_{mp}^{D,0}}{(N_{mp}^{D} + 1)b}\right) - \left(\frac{N_{mp}^{D,0}(1 + \kappa_{mp})}{(N_{mp}^{D} + 1)b}\right)\tau^{2} W_{p} \\ &= \alpha_{mp}^{C} - \beta_{mp}^{C} W_{p} \quad (11) \end{aligned}$$

Then, by summing prefectural derived demand functions, the aggregate derived demand in prefecture p is obtained as

$$Q_{p}^{nv} = \sum_{m=1}^{M_p} \alpha_{mp}^{C} - \sum_{m=1}^{M_p} \beta_{mp}^{C} W_{p}. \quad (12)$$

One thing that should be emphasized here is that α_{p}^{C} and β_{p}^{C} depends on the extent of vertical integration and marginal costs of firms in local market m and thus can be different from one market to another.

On the other hand, vertically integrated firms demand the amount of cement needed to supply their equilibrium quantities $s_{d^i mp}$ internally. Therefore, the demand for upstream firm i's cement in prefecture p becomes

$$q_{p}^{v} = \tau \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^{D}} s_{d^i mp} \quad (13)$$

As in equation (8), this amount is realized as the result of downstream equilibria in local markets and depends on market level demand shifters, own and other firms' marginal costs, the number of concrete firms, and the input price, W_p. This means that the amount of internal cement demand eventually depends on the amount of cement supplied to the external input market in prefecture p. This fact is taken into account when upstream firms decide how much they supply to independent concrete firms, that is, q_{ip}^{nv}.

5.3 Demand from Other Industries and Total Cement Demand

The ready-mixed concrete industry accounts for the vast majority of cement demand. In fact, on average, the industry consumes around 80% of the total cement supply in the Chugoku region. Therefore, the demand coming from this sector has a great importance in prefectural input markets in the region. On the other hand, other sectors that uses cement as an input in their production play a minor role in explaining the total cement demand (in prefectures in the region). Among these other industries, the largest industry is the cement related product industry and its consumption share is around 10%. The second largest shares only 1% of the total cement consumption. Each sector is tiny. Given this fact, it may be acceptable to focus on cement-concrete relationship. It may be able to abstract away these sectors altogether. However, if they are put together, the rest industries amounts to around 20% of the total demand and, although each sector is tiny, they, as a whole, cannot be negligible.

The present study takes into account the demand from sectors other than the ready-mixed concrete industry but in a simpler way. Specifically, although, to derive the demand function in the ready-mixed markets, how concrete firms compete is detailed, how each firm's demand arises is abstracted away and, instead, just assume that (firms in) these sectors need cement for their production. [14] The aggregate demand from

[14] In an ideal situation, all of other downstream industries are modeled as the ready-mixed concrete markets are. However, due to data limitations, it is hard to describe and estimate firm behavior in these industries. Therefore, the current study has to give up detailing these industries. This approach that makes the analysis feasible is admittedly a compromise. However, the total cement

other sectors is specified as the following form.

$$Q_p^O = \alpha_p^O - \beta_p^O W_p \quad (14)$$

Q_p^O is the amount of cement consumed in industries other than the ready-mixed concrete firms. When estimating the above demand function, parameters α_p^O and β_p^O are assumed to be time-invariant. If firms behavior is not explicitly modeled, this restriction could be got rid of. In other words, at this cost, the analysis can be simplified.

By combining the demand function of the ready-mixed concrete markets with the aggregate demand of the rest of sectors in a particular prefecture, the total cement demand function is derived as follows,

$$Q_p^C + Q_p^O = (\alpha_p^C + \alpha_p^O) - (\beta_p^C + \beta_p^O)W_p = \alpha_p - \beta_p W_p \quad (15)$$

where $Q_p^C = \sum_{m=1}^{M_p} Q_{mp}^C$, $\alpha_p^C = \sum_{m=1}^{M_p} \alpha_{mp}^C$, and $\beta_p = \sum_{m=1}^{M_p} \beta_{mp}$ (M_p is the number of local ready-mixed concrete markets in prefecture p). Finally, the total inverse demand function is written as

$$W_p = A_p - B_p Q_p. \quad (16)$$

It should be noted that, due to the nature of the derived demand function of ready-mixed concrete firms that varies with local markets, the intercept and slope of the aggregated demand function of all prefectural ready-mixed concrete markets can be different in different prefectures. Therefore, the total (inverse) demand function can vary with prefectures as well.

5.4 Upstream Firm Decision

In this subsection, how upstream firms decide the amount of supply is described. In the previous subsection, the downstream equilibrium outcomes are explained and the

consumption in industries other than the ready-mixed concrete is not large and specification errors from this parsimonious modeling are expected not to be serious.

total derived demand functions are defined (as a function of the downstream equilibrium outcomes). Vertically integrated downstream concrete firms demand the amount of input necessary to supply their equilibrium supply from their vertically related upstream firms. This means that downstream equilibrium determine the level of quantity supplied to concrete plants and upstream firms' role is somewhat indirect because they can control downstream firms' behavior through changing input price.

Upstream firms directly determines the amount of cement supplied to prefectural cement markets. That is, a cement firm determines q_{ip}^{nv} in order to maximize its profit.

As usual in an oligopolistic situation, upstream firms exercise their market power to set quantities (under their capacity constraints by the cartel agreement). One significant difference from a usual oligopoly without vertical integration is the point that a change in cement price W_p results in a change in the profits of vertically integrated downstream firms because unintegrated downstream plants' marginal costs varies with the cement price, W_p. A change in W_p brought by changing q_{ip}^{nv} leads to a change in the equilibrium output of downstream firm d^i, s_{d^imp}, because s_{d^imp} is a function of W_p as in (8), and then leads to the corresponding change in the cement demand of this downstream firm, $q_{d^imp}^{v} = \tau s_{d^imp}(W_p)$. Therefore, upstream firms need to take into account this additional effect of changing the level of supply on their downstream firms' profits when choosing q_{ip}^{nv}. Conversely, by choosing q_{ip}^{nv}, upstream firm i eventually controls the vertically integrated downstream firms' equilibrium output levels and decides their equilibrium profits.

To reflect these structures of the profit maximizing problem facing upstream firms, by emphasizing the dependence of W_p on Q_p, the Lagrangean in (3) is redefined as

$$L(q_i^{nv}, \lambda_i) = \sum_{p=1}^{P} \left\{ \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^D} \left\{ \varsigma_{d^imp} \pi_{d^imp}^{D} (W_p(Q_p)) + (W_{d^imp}(W_p(Q_p)) - c_{ip}^{U,\lambda}) \tau s_{d^imp}(W_p(Q_p) \right\} \right\}$$

$$
\begin{aligned}
&+\sum_{p=1}^{P}\left\{(W_p(Q_p)-c_{ip}^{U,\lambda})q_{ip}^{nv}\right\}\\
=\;&\sum_{p=1}^{P}\left\{\sum_{m=1}^{M_p}\sum_{d^i=1}^{N_{imp}^D}\left\{\varsigma_{d^imp}\pi_{d^imp}^D(W_p(Q_p))+(1-\kappa_{d_imp})(W_p(Q_p)-c_{ip}^{U,\lambda})\tau s_{d^imp}(W_p(Q_p))\right\}\right\}\\
&+\sum_{p=1}^{P}\left\{(W_p(Q_p)-c_{ip}^{U,\lambda})q_{ip}^{nv}\right\} \qquad (17)
\end{aligned}
$$

where $\lambda_i\bar{q}_i$ is dropped because this term does not affect the solution. κ_{d_imp} represent the input pricing rule that is defined in (7) that determines input price W_{d^imp}. s_{d^imp} is the equilibrium supply of vertically integrated downstream firm d^i given the market price W_p and the amount of cement that this firm demand to produce s_{d^imp} corresponds to the individual cement demand of this firm d^i.

The first-order optimality condition for q_{ip}^{nv} becomes

$$
\begin{aligned}
&\sum_{m=1}^{M_p}\sum_{d^i=1}^{N_{imp}^D}\left\{\varsigma_{d^imp}\frac{\partial\pi_{d^imp}^D}{\partial q_{ip}^{nv}}+(1-\kappa_{d^imp})\tau\left(\frac{\partial W_p}{\partial q_{ip}^{nv}}s_{d^imp}+(W_p(Q_p)-c_{ip}^{U,\lambda})\frac{\partial s_{d^imp}}{\partial q_{ip}^{nv}}\right)\right\}\\
&\qquad+\frac{\partial W_p}{\partial q_{ip}^{nv}}q_{ip}^{nv}+(W_p(Q_p)-c_{ip}^{U,\lambda})=0. \qquad (18)
\end{aligned}
$$

Terms in the bracket represents the effects of vertical integration on the decision of optimal q_{ip}. The first term is the change in $\pi_{d^imp}^D$ by changing q_{ip}^{nv}, which is weighted by firm i's stake in the downstream firm d^i. This effect arises through a change in W_p. As a result, the sign of $\frac{\partial\pi_{d^imp}^D}{\partial q_{ip}^{nv}}$ depends on κ_{d^imp} (and thus ς_{d^imp}). For instance, in the cases of relatively small values of κ_{d^imp}, $\frac{\partial\pi_{d^imp}^D}{\partial q_{ip}^{nv}}$ can become positive because this firm's input price, W_{d^imp}, largely depends on the market price W_p. Otherwise, the derivative shows a negative sign, as usually expected. The second term is the sum of the marginal profits of selling inputs to integrated downstream firms internally. The sign of $\frac{\partial W_p}{\partial q_{ip}}$ is always negative while the sign of $\frac{\partial s_{d^imp}}{\partial q_{ip}}$ is not determined. Therefore, how the second term affects is not determined in general.[15]

[15] To get an intuition of the role of vertical integration in this optimality problem, suppose if all

By aggregating upstream firms' FOCs, the equilibrium market supply at prefecture p is obtained as the following form

$$Q_p^* = \frac{\Psi_p}{\Omega_p}. \tag{19}$$

The denominator and numerator are

$$\Omega_p = (N_p^U+1)B_p - 2\frac{(\tau B_p)^2}{b}\sum_{i=1}^{N_p^U}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N_{ip}^D}\left\{\varsigma_{d^imp}\left(\Delta_{d^imp}\right)^2 + (1-\kappa_{d^imp})\Delta_{d^imp}\right\} \tag{20}$$

$$\begin{aligned}
\Psi_p = & -2\frac{\tau B_p}{b}\sum_{i=1}^{N_p^U}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N_{imp}^D}\varsigma_{d^ip}\Delta_{d^imp}\Gamma_{d^imp} - 2\frac{\tau^2 A_pB_p}{b}\sum_{i=1}^{N_p^U}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N_{imp}^D}\varsigma_{d^ip}\left(\Delta_{d^imp}\right)^2 \\
& -\frac{\tau B_p}{b}\sum_{i=1}^{N_p^U}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N_{imp}^D}(1-\kappa_{d^imp})\Gamma_{d^imp} - \frac{\tau^2 A_pB_p}{b}\sum_{i=1}^{N_p^U}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N_{imp}^D}(1-\kappa_{d^imp})\Delta_{d^imp} \\
& -\frac{\tau^2 B_p}{b}\sum_{i=1}^{N_p^U}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N_{imp}^D}(1-\kappa_{d^imp})(A_p - c_{ip}^{U,\lambda})\Delta_{d^imp} + N_p^UA_p - \sum_{i=1}^{N_p^U}c_{ip}^{U,\lambda}
\end{aligned} \tag{21}$$

$$\begin{aligned}
\Delta_{d^imp} &= \frac{(N_{mp}^D+1)\kappa_{d^imp} - (1+\kappa_{mp})}{(N_{mp}^D+1)} \\
\Gamma_{d^imp} &= \frac{a_{mp} - (N_{mp}^D+1)(\tilde{c}_{d^imp}^D + \tau\kappa_{d^imp}c_{ip}^U) + \tilde{c}_{mp}^{D,\tau\kappa c^U} + \tau\kappa c_{mp}^U}{(N_p^D+1)}.
\end{aligned}$$

With this equilibrium output level, the equilibrium quantity of upstream firm i is provided by

$$q_{ip}^{nv*} = \frac{\Phi_{ip}}{B_p} \tag{22}$$

κ_{d^imp} are relatively large. If this is the case, the effect of vertical integration on optimal q_{ip} is clear. Terms in the blanket as a whole act as the marginal cost. Then, the more downstream plants an upstream firm owns, the less it supplies to the prefectural market.

$$
\begin{aligned}
\Phi_{ip} \;=\; & -2\frac{\tau B_p}{b}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N^D_{imp}} \varsigma_{d^ip}\Delta_{d^imp}\Gamma_{d^imp} - 2\frac{\tau^2 A_p B_p}{b}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N^D_{imp}} \varsigma_{d^ip}\left(\Delta_{d^imp}\right)^2 \\
& -\frac{\tau B_p}{b}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N^D_{imp}}(1-\kappa_{d^imp})\Gamma_{d^imp} - \frac{\tau^2 A_p B_p}{b}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N^D_{imp}}(1-\kappa_{d^imp})\Delta_{d^imp} \\
& -\frac{\tau^2 B_p}{b}\sum_{m=1}^{M_p}\sum_{d^i=1}^{N^D_{imp}}(1-\kappa_{d^imp})(A_p - c^{U,\lambda}_{ip})\Delta_{d^imp} + A_p - c^{U,\lambda}_{ip} \\
& +2\sum_{m=1}^{M_p}\sum_{d^i=1}^{N^D_{imp}}\left((1-\kappa^i_{d^imp})\Delta^i_{d^imp} + \delta_{d^imp}(\Delta_{d^imp})^2\right)\frac{(\tau B_p)^2}{b}Q^*_p - B_p Q^*_p. \qquad (23)
\end{aligned}
$$

6 Estimation

This section explains the estimation of parameters in the theoretical model. The estimation approach taken in the present study is essentially the standard approach that is used in other empirical studies of homogeneous good industries. Although it is very familiar to the field of industrial organization, due to the successive oligopolistic structure of the theoretical model, it takes a few steps more than the standard structural estimation of a homogeneous product market.

The main empirical objects are the parameters of the profit functions of downstream and upstream firms. The demand function facing ready-mixed concrete firms and the marginal costs of these firms are first estimated. Then, the market demand for cement is derived as the result of the downstream equilibrium, using these estimated demand and marginal costs. Coupled with other sectors' demand functions, the total derived demand function for cement is obtained.

Next, with the derived demand function and the profit functions of integrated downstream firms, the upstream firms' marginal costs, which include the shadow marginal costs, are backed out by inverting the first order profit maximizing condition of upstream firms.

Then, the last step is to separately estimate parameters of the marginal cost function and shadow marginal costs, λ_{it}. At this step, the JFTC monitoring period is leveraged. With the assumption that this period provides a competitive benchmark, the shadow marginal costs are estimated as the differences in the marginal cost between the cartel and the JFTC monitoring periods.

6.1 Demand and Marginal Cost in The Ready-Mixed Concrete Markets

The demand and (marginal) cost functions in the ready-mix concrete industry are estimated. In addition to these empirical objects, the derived demand for cement is obtained as a result of downstream competition. The quantity demanded, that is, the level of cement used in this industry, is proportional to the total amount of equilibrium supply of independent ready-mix concrete firms.

6.1.1 Demand Function

The first empirical object is the (inverse) demand function and the following linear (inverse) demand function is assumed and estimated.

$$P_{mpt} = \tilde{a} Z_{mpt} - \tilde{b} S_{mpt} + \epsilon_{mpt} \tag{24}$$

P_{mpt} and S_{mpt} indicate the quantity demanded and the equilibrium price at market m in prefecture p in time t while Z_{mpt} is the demand shifter, which is the construction employment in local market m. One issue here is the data limitation. As explained in the data section, local ready-mixed concrete market level equilibrium quantities are not obtained while data on local concrete prices and demand shifters are available. Therefore, instead of local market level demand functions, the (prefecture level) aggregate demand function is considered. The aggregate demand function is defined as just the sum of all local market demand functions in prefecture p.

$$S_{pt} = aZ_{pt} - bP_{pt} + \epsilon_{pt} \tag{25}$$

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 $\epsilon_{pt} = \sum_{m=1}^{M_p} \epsilon_{mpt}$. Admittedly, this aggregation has some limitations. For instance, flexible specifications on the parameters, such as different slopes in different local markets, are not allowed. Parameters are assumed to be constant across local markets. This inflexibility that stems from the data limitation is of course a limitation. However, at the same time, the assumption of demand parameters constant across markets is widely used in empirical work in estimating demand functions.[16]

Prefecture level fuel (gasoline) prices are used as the instrumental variable. The reason why this variable can serve as an instrumental variable is that a change in the fuel price affects the delivery costs of ready-mixed firms (delivery costs from concrete plants to construction sites) and it also influences the delivery costs of cement firms (delivery costs from distribution centers mainly to ready-mixed concrete plants) and in turn affects the cement market price W_p, which is a component of the marginal cost of downstream firms. Thus, fuel (gasoline) price can become an IV in order to estimate the downstream demand function.

6.1.2 Marginal Cost

The marginal costs of ready-mixed concrete firms are recovered using the first order conditions of downstream firms' profit maximizing behavior, with estimates of the parameters in the demand function, as usually done in the IO literature. Vertically integrated concrete firm d^i's marginal cost is estimated using the first order optimality

[16] Another potential limitation is the functional form assumption.

condition

$$\hat{c}_{d^i mpt} \quad = \quad \hat{P}_{mpt} + \frac{\partial \hat{P}_{mpt}}{\partial s_{d^i mpt}} s_{d^i mpt}, \quad \forall i = 0, 1, \ldots, N^U \tag{26}$$

For the derivation of the derived demand function, the following expression is useful. Market cement price is subtracted from the marginal cost of firm d^i and the rest of the marginal cost is

$$\hat{\tilde{c}}^{D,\lambda}_{d^i mpt} = \hat{c}_{d^i mpt} - \tau(1 - \kappa_{d^i mpt})W_{pt} = \hat{\tilde{c}}_{d^i mpt} + \tau\kappa_{d^i mpt}\hat{c}^{U,\lambda}_{ip}. \tag{27}$$

where $\kappa_{d^i mpt}$ represents the pricing rule of firm i and $\hat{\tilde{c}}_{d^i mpt}$ is the marginal cost except cement price W_{pt}. The above subtraction is possible because W_{pt} and $\tau\kappa_{d^i mpt}$ are observable. $\hat{\tilde{c}}^{D,\lambda}_{d^i mpt}$ is the part of the marginal cost, which is not influenced by W_{pt}.[17]

In the case of unintegrated concrete firms ($\kappa_{d^0 mpt} = 0$), the above expression becomes a more succinct form as

$$\hat{c}_{d^0 mpt} - \tau W_{pt} = \hat{\tilde{c}}^{D}_{d^0 mpt}. \tag{29}$$

6.1.3 Derived Demand for Cement

The (estimated) cement demand derived from a local ready-mixed concrete market is obtained by plugging-in $\hat{\tilde{c}}^{D,\lambda}_{d^i mpt}$ in equation (11).

$$\begin{aligned} Q^C_{mpt} = \tau S_{mpt} \quad &= \quad \tau \left(\frac{N^{D,0}_{mpt}(\hat{a}_{mpt} + \hat{\tilde{c}}^{D,\lambda}_{mpt}) - (N^D_{mpt} + 1)\hat{\tilde{c}}^{D,0}_{mpt}}{(N^D_{mpt} + 1)\hat{b}} \right) - \left(\frac{N^{D,0}_{mpt}(1 + \kappa_{mpt})}{(N^D_{mpt} + 1)\hat{b}} \right) \tau^2 W_{pt} \\ &= \quad \hat{\alpha}^C_{mpt} - \hat{\beta}^C_{mpt} W_{pt} \end{aligned} \tag{30}$$

where $\hat{a}_{mpt} = \hat{a}Z_{mpt}$, $\hat{\tilde{c}}^{D,\lambda}_{mpt} = \sum_{i=0}^{N^U_p} \sum_{d^i=1}^{N^D_{impt}} \hat{\tilde{c}}^{D,\lambda}_{d^i mpt}$ and $\hat{\tilde{c}}^{D,0}_{mpt} = \sum_{d^0=1}^{N^D_{0mpt}} \hat{\tilde{c}}_{d^0 mpt}$. The prefecture level derived demand function is the sum of local markets' derived demand

[17] Remember that the marginal costs of d^i consists of cement price and other costs, that is,

$$c_{d^i mpt} = \tilde{c}_{d^i mpt} + \tau W_{d^i mpt} = \tilde{c}_{d^i mpt} + \tau \left(\kappa^i_{dmpt} c^{U,\lambda}_{ipt} + (1 - \kappa^i_{dmpt}) W_{pt} \right). \tag{28}$$

functions,

$$Q_{pt}^C = \hat{\alpha}_{pt}^C - \hat{\beta}_{pt}^C W_{pt} \tag{31}$$

where $\hat{\alpha}_{pt}^C = \sum_{m=1}^{M_p} \hat{\alpha}_{mpt}^C$ and $\hat{\beta}_{pt}^C = \sum_{m=1}^{M_p} \hat{\beta}_{mpt}^C$.

6.2 Other Industries' Demand for Cement

As explained earlier, because there are data limitations on firms in the rest of the industries using cement as an input and these sectors are less important than the ready-mixed concrete industry, how the demand for cement in these industries arises is abstracted away from the theoretical model and, instead, it is just assumed that firms in these sectors constitutes demand as final consumers do, which is usually assumed in studies of homogeneous product industries.

With this assumption making the analysis tractable, the estimation of the demand function becomes straightforward. The following inverse demand function is estimated.

$$W_{pt}^o = a^o Z_{pt}^o - b^o Q_{pt} + \epsilon_{pt}^o \tag{32}$$

where W_{pt} is the price of cement in prefecture p in time period t and Q_{pt}^o is the total amount of cement demanded in industries other than the ready-mixed concrete industry in prefecture p. Z_{pt}^o is the demand shifter, which is proxied by the number of construction workers.

As an instrumental variable, prefecture level fuel (gasoline) price is used as used in the estimation of the ready-mixed concrete demand function. As explained earlier in the section describing the estimation of the ready-mix concrete demand curve, fuel price affects the cost of cement delivery. Thus this variable is considered as a good supply shifter for estimating the demand function.

6.3 Upstream Marginal Cost

Upstream firms' marginal costs are backed out by solving their profit maximizing conditions with respect to marginal costs as usually done in the empirical IO literature. The amount of quantity supplied by upstream firm i to the cement market reveals its marginal cost c^U_{ipt}.

By using the first order condition for optimal market supply q^{nv}_{ipt}, the marginal cost of cement firm i is written as the following form

$$c^{U,\lambda}_{ipt} = W_{pt} + \frac{\sum_{m=1}^{M_p} \sum_{d^i=1}^{N^D_{impt}} \left\{ \varsigma_{d^i mpt} \frac{\partial \Pi^D_{d^i mpt}}{\partial W_{pt}} \frac{\partial W_{pt}}{\partial q^{nv}_{ipt}} + (1-\kappa_{d^i mpt}) \frac{\partial W_{pt}}{\partial q_{ipt}} \tau s_{d^i mpt} \right\} + \frac{\partial W_{pt}}{\partial q^{nv}_{ipt}} q^{nv}_{ipt}}{\left(1 + \sum_{d^i=1}^{N^D_{d^i mpt}} (1-\kappa_{d^i mpt}) \tau \frac{\partial s_{d^i mpt}}{\partial q_{ipt}}\right)} \tag{33}$$

where it should be remembered that $c^{U,\lambda}_{ipt} = c^U_{ipt} + \lambda_{it}$. Therefore, by inverting the first order optimality condition for q^{nv}_{ipt}, what can be backed out is the effective marginal cost $c^{U,\lambda}_{ipt}$, which includes not just the (physical) marginal cost, c^U_{ipt}, but also the shadow marginal cost, λ_{it}.

The marginal cost function is specified as flexible as possible by including firm-prefecture and prefecture-time fixed effects.

$$\begin{aligned} \hat{c}^{U,\lambda}_{ipt} &= c^U_{ipt} + \lambda_{it} \qquad (34) \\ &= w_{ipt}\gamma_1 + v_{it}\gamma_2 + \epsilon_{ipt} + \lambda_{it} \end{aligned}$$

w_{ipt} represents a vector of firm-prefecture level variables, including. w_{it} represents a vector of firm-level variables. η_{ip} is firm-prefecture fixed effect while μ_{pt} is prefecture-time fixed effect. w_{ipt} indicates firm-prefecture characteristics (includes size of distribution network) v_{it} is firm-year characteristics (includes productivity)

One of the important firm characteristics is the size of the distribution network, which is represented by the number of cement service stations from which a cement firm deliver its cement to customers. The larger the network size becomes, a cement firm more easily arranges delivery. Therefore, the number of distribution centers affects the marginal cost. The number of cement service stations in prefecture p is included, which indicates the size of the distribution network of firm i at p.

For the cost function estimation, it is important to distinguish the physical marginal costs, c^U_{ipt}, and the shadow price, λ_{it}. To this end, the present study takes advantage of the period after the cartel was convicted. After the cartel was convicted, cement firms involved were under the JFTC's monitoring for three years. During these three years, firms were required to report their sales activities to the JFTC monthly. This monitoring period of 1991-1993 is expected to provide a good (competitive) benchmark for the cement industry. It is assumed that, during this period of the JFTC monitoring, a Cournot equilibrium is a good approximation to firm behavior in the cement industry.

More precisely, the JFTC monitoring (1991-1993) provides the competitive benchmark and each λ_{it} is estimated relative to the mean of firm-year fixed effects during the monitoring period. That is, (the mean of) firm-year effects during the monitoring period provides benchmark (competitive) level of unobserved cost shock and, coupled with the assumption that during the cartel that unobserved shock level was unchanged, the difference between firm-year effects during the cartel and those after the conviction provides an estimate of λ_{it}.

$$\lambda_{it} = \lambda'_{it} - \overline{\lambda}_{i91-93}, \quad t \in \{1985, 1984, \ldots, 1990\} \tag{35}$$

where λ'_{it} is firm-year effects in 1985-1990 and $\overline{\lambda}_{i91-93}$ is the mean of firm-year effects in 1991-93.

The period after the cartel helps separately estimate the marginal cost (function) and the shadow marginal costs, which arises only during the cartel period. However, one potential concern is that a time-varying unobserved factor(s) is present and, for instance, it changes across different regimes. If this is the case, the key assumption mentioned above can be violated.That is, firm level unobserved factors are not constant before and after the detection and estimates of the shadow marginal cost are contaminated by the time-varying unobserved factors present in the (physical) marginal cost function.

A candidate of the main unobserved factors that invalidate the key assumption is time-varying (firm-level or industry-level) efficiency. For instance, after the detection, the industry became more competitive and then the firm-level or industry-level productivity and/or efficiency at the distribution stage increased.[18] Alternatively, the opposite story might happen. During the cartel, the total supply quantities were fixed and so prices were. This environment might create incentive to improve efficiency in order to obtain more profits. In either case, the presence of any efficiency change in any direction at any stage that happened in the course of the cartel and/or after the detection of the cartel potentially contaminates estimates of shadow marginal costs. Therefore, reducing the influence of these potential efficiency changes is necessary.

Regarding efficiency changes at the production stage, plant level productivity is introduced in the regression analysis and, even if there are changes in the course of and after the cartel, the influence of these changes on the marginal cost is well captured. Thus, it is unlikely that estimates of λs are contaminated by changes in productivity of cement producing plants. On the other hand, with respect to efficiency at the distribution stage, this is truly an unobservable variable and cannot be included as an explanatory variable unlike (plant level) productivity. Due to this reason, a different approach is employed.

The approach that is taken here is to allow an important parameter in the marginal

[18]Backus (2020) finds that firms that are in more competitive markets are more productive, by studying producing plants in the US ready-mixed concrete industry.

cost function to become time (or firm-time) varying and to check whether or not the parameter is changed from one time period to another. The most important variable at the delivery stage is the number of cement distribution centers (in a prefecture), which measures the size of distribution network, as explained earlier. The parameter on this variable indicates how efficiently cement firms use their distribution network to supply their products. Therefore, if firms became more (or less) efficient to utilize their distribution network, the efficiency gain (or loss) will be reflected as a change in the parameter. Holding the number of distribution centers unchanged, when a cement firm uses its current distribution network more efficiently, the size of the coefficient (in absolute value) becomes larger (or vice versa). In other words, any change in the coefficient is the reflection of a change in efficiency at the delivery stage.

Admittedly, this approach may not be a perfect resolution to the potential concern. The reason is that it assumes that efficiency changes in the delivery stage influence cement firms' marginal costs only though the way that they use their distribution network. Therefore, it might miss other forms of efficiency (gains and losses) and these efficiencies could be included in estimates of shadow prices. However, as explained before, how to utilize their distribution centers is undoubtedly one of the most important concerns for cement firms at the distribution stage. It is highly likely that (at least some of) the change appears as a change in the coefficient. It is no doubt that at least a (hopefully major) part of efficiency change (if it happens) is captured by the time dependent coefficient. Although limitations should be admitted, the approach employed here helps alleviate or minimize the potential issue raised in the estimation of the marginal cost function and shadow prices.

7 Estimation Results

This section provides and explains the estimation results. First, the estimation results of the downstream industries are presented. Next, the marginal cost function estimation of the upstream cement firms is presented. Then, estimates of the shadow marginal costs and the implications of these shadow costs are discussed. Lastly, some potential issues regarding the estimation is discussed.

7.1 Downstream: Ready-Mixed Concrete and Other Sectors

For the ready-mixed concrete markets, the demand function is estimated and then marginal costs of concrete firms are recovered. With these marginal cost estimates, the demand for cement of each concrete firm is derived from the (equilibrium) outcomes in local concrete markets. The total market demand arising from the concrete industry is estimated as the sum of unintegrated concrete firms' cement demand.

7.1.1 Demand Function

The concrete demand function (25) is estimated using the two stage least squares (2SLS) with fuel (gasoline) price as the instrumental variable. In Table (4), the estimation results are presented. There are several different specifications depending on the use of different fixed effects.

The preferred specification is one with year fixed effects. The elasticity is reasonable (about 0.5 when evaluated at the mean). Once introducing both prefecture and year effects, important variations are captured with these fixed effects and imprecise estimates are produced.

7.1.2 Marginal Cost

With the estimates of the parameters of demand function, the marginal costs of both integrated and unintegrated ready-mix concrete firms are backed out by using the first order conditions for profit maximization. After the marginal cost of each ready-mixed concrete firm is backed out, the cement price-subtracted marginal cost is also obtained. As in equation (10), these marginal costs of concrete firms are used to express the derived demand for cement. By plugging these input price subtracted marginal cost estimates into (9) and summing up unintegrated concrete firms' demand, the estimated aggregate derived demand function is obtained.

7.1.3 Downstream Industries Other Than Ready-Mixed Concrete

Firms in industries other than the ready-mixed concrete industry demand cement as an input for their production. The cement demand function that arises from these firms' demand for cement is estimated. The estimation results of the demand function (32) is presented in Table 5. As is done in the case of the ready-mix concrete industry, several specifications are used. Different specifications produces different estimates of the parameters of the demand function. The preferred specification is one with year effects as in the case of the ready-mixed concrete industry. The reason is that important prefectural differences are captured by prefecture fixed effects and only little variations are left to estimate parameters. As a result, exactly the same as the case of the ready-mixed concrete industry, the introduction of the full sets of prefecture and year fixed effects produces imprecise estimates of the parameters.

Combining two demand functions produces the total (market) demand for cement. It is within a reasonable range considering the nature of cement. The price-elasticity is about 0.8 at the evaluated the means of price and quantity.

7.2 Upstream

With estimates of the total derived demand function at hand, the empirical objects are the marginal costs of upstream firms and the shadow marginal costs of these firms. By exploiting each firm's profit maximization condition for the market supply as in (33), the effective marginal cost is recovered. Then, the marginal cost and the shadow cost are separately estimated with the approach explained in Section 6. To recover the marginal costs, an input pricing rule determining input prices of integrated concrete firms is needed. The pricing rule proportional to the extent of vertical integration, $\kappa_{d^i mpt} = \varsigma_{d^i mpt}$, the rule that more than 50% owned firms are supplied at their upstream firm's marginal cost, $\kappa_{d^i mpt} = 1$ if $\varsigma_{d^i mpt} > 0.5$ and $\kappa_{d^i mpt} = 0$ otherwise, and the rule that 100% owned firms are supplied at their upstream firm's marginal cost, $\kappa_{d^i mpt} = 1$ if $\varsigma_{d^i mpt} = 1$ and $\kappa_{d^i mpt} = 0$ otherwise.

The results of the marginal cost function estimation are presented in Table 6. The size of distribution network in a prefecture, which is measured by the number of distribution centers, is an important factor affecting the (physical) marginal cost of a cement firm, as expected. Similarly, the size of distribution network in the area that prefecture is located in is another important marginal cost determinant.

In estimating the shadow prices, the period of the JFTC monitoring provides a benchmark for firms' unobserved factors in their marginal cost and helps separately estimate shadow marginal costs and unobserved factors influencing (physical) marginal cost. The (sum of) unobserved factors in the marginal cost of a cement firm are captured by introducing the after cartel dummy variable for this firm. This dummy variable serves as the reference level of the unobserved factors and the shadow prices are estimated based on this reference state.

For estimating the shadow marginal costs, several different specifications on λ_{it}

are used. The first specification is that λ_{it} is introduced as firm-year fixed effects. This specification is appealing obviously an ideal specification because it is the most flexible specification. On the other hand, there are only five observations (prefectures) per firm-year to estimate the shadow costs. Therefore, this cannot provide consistent estimates of the shadows marginal costs and might produces imprecise estimates.

Therefore, alternative specifications on λ_{it} are considered. The second specification is another polar case. That is, all firms' shadow costs are assumed the same (but still time-varying), $\lambda_{it} = \lambda_t$. Given the fact that the market shares were (almost) constant before and after the cartel, it may not be possible that the shadow prices (in the same year) were the same amount across firms.[19] However, as the simplest approximation, this is estimated and examined how this fits the data is examined.

The third and forth specifications are ones in between the two polar specifications: the shadow prices are assumed to depend on firm variables, the market share realized just before the cartel started and the size of distribution network in the region. Specifically, in the third specification, the shadow cost is defined as $\lambda_{it} = \lambda_t + \lambda_t \times s_{i1984}$. The reason to choose the market shares realized in 1984 is that, by looking at the market shares of 1984 and the following years after the cartel was initiated, it is obvious that the cartel intended to use these market shares as the share allocation rule.

In the fourth specification, λ_{it} is defined as $\lambda_t + \lambda_t \times x_{it}$. x_{it} is the size of distribution network of firm i in the region (measured by the total number of firm i's distribution centers in the region). This is a very similar specification to the above one although it is a little bit flexible than the previous one because x_{it} changes overtime.

The results are provided in Table 6. By looking at the results from the second

[19] For instance, in a classic Cournot model, if the same shadow cost is imposed on all firms, every firm reduces the same amount of supply quantity. This does not produce the same market shares as before the introduction of shadow price unless all firms have the same marginal cost. In the case of the current study's model,

to the fourth specifications, it is confirmed that estimates of the mean of the shadow costs are not influenced by the introduction of firm level variables. In addition, the coefficients on firm variables are estimated statistically insignificant and economically very marginal.

In Table 7 and 8, by introducing the time (and firm) dependent coefficient on the size of distribution network, the presence of a change in unobserved efficiency level (in the distribution stage) is checked.[20] First, dummies for years during the cartel are introduced and interacted with the size of distribution network. Second, by introducing firm-cartel dummies, the presence of firm level changes in efficiency before and after the cartel are examined. In the former case, the estimates of time varying coefficient are not statistically significant and at the same time the sizes of these estimates are quite small. On the other hand, in the second case, some estimates are statistically significant and economically sizable. For some cement firms, unobserved efficiencies in the delivery stage might be different across the two different regimes.

In sum, the first preferred specification is one with year fixed effects as the shadow marginal costs and interactions between the distribution network size and firm-cartel fixed effects. The simplest specification is used as a benchmark specification. With respect to the specification with firm-year effects as the shadow marginal costs, this specification is the most flexible one . However, estimates are imprecise and, in addition to the impreciseness, the introduction of these dummies does not improve the fit of the model significantly.

[20]It is remembered that any efficiency change in the production stage is already captured by firm level productivity.

8 Analysis of Cartel Incentive

In this section, firms' incentives to collude are measured in different market structures and whether vertical relationship between upstream and downstream firm facilitates upstream collusion or not is examined. More concretely, the critical discount factors in different market configurations with and without vertical integration are calculated based on the estimates of demand and cost parameters in the previous section and they are compared to see if vertical integration between cement and concrete firms facilitates cement firms' collusion.

Then, in addition to the analysis of changes in the critical discount factors, how vertical integration influences cartel incentive is studied in a deeper level. The theoretical literature identifies the contradicting effects of vertical integration on cartel incentive, as Nocke and White (2007,2011) and Normann (2008).

Further, one more experimental exercise is conducted to look at the effect of downstream competition on upstream firms' incentives to collude. This exercise asks whether tougher downstream competition hinders upstream collusion or increases the incentive to collude. In order to answer this question, the market definition in the ready-mixed concrete industry is altered. That is, a broader market definition than the one used in this study so far is used and competition in ready-mixed concrete markets gets tougher. Under this counterfactual environment, upstream firms' incentive to collude is examined.

8.1 Upstream Firms' Incentive to Collude

The main question to be answered is whether or not vertical integration facilitates upstream collusion. In order to measure upstream firms' incentive to collude, the following critical discount factor is calculated for both the actual market structure and counterfactual market structures. The critical discount factor under market structure s is

$$\underline{\delta}^s = \max_{i \in N} \frac{\hat{\Pi}_i^{DEV,s} - \hat{\Pi}_i^{COL,s}}{\hat{\Pi}_i^{DEV,s} - \hat{\Pi}_i^{PUN,s}} \tag{36}$$

where $\hat{\Pi}_i^{DEV,s}$ is the deviation profit of upstream firm i and $\hat{\Pi}_i^{COL,s}$ indicates the cartel profit of firm i while $\hat{\Pi}_i^{PUN,s}$ represents firm i's per-period profit in the punishment phase where the infinite repetition of Cournot competition is assumed as the punishment scheme.

When calculating the critical discount factors in the actual market structure, predicted values of upstream firms' internal and market supply quantities, instead of actual values of these. By using estimates of the shadow prices (as well as the marginal cost functions), the predicted cartel equilibrium profits are obtained as well as upstream firms' supply quantities to both local cement markets and own downstream concrete firms. Then, by eliminating the shadow prices of all upstream firms, (Cournot) competitive equilibrium profits are obtained.

Regarding the calculation of the deviation profits, how to define the deviation profits in the presence of vertical integration becomes an issue. The present study borrows the idea of Normann (2009) to address this issue. The point is that his approach takes into account the reaction effect that represents the reaction of vertically integrated firms in the downstream when one upstream firm deviates. That is, when one upstream firm, regardless of its status of vertical integration, deviates, the input price changes and thus other upstream firms can realize the deviation at this stage. This means that vertically integrated upstream firms can react to this deviation at the downstream market. Therefore, the deviator's profit is reduced by the (prompt) reaction of vertically integrated firms because the downstream turns to be competitive.

In the context of the present study, the reaction effect works in the following way.

Given that other firms' supply quantities (to local concrete markets) are fixed at the levels that the cartel designates, firm i tries to maximize its profit by choosing q_{ip}^{nv} and setting the input prices of its downstream firms based on c_{ip}^{U} not $c_{ip}^{U,\lambda}$. However, when q_{ip}^{nv} exceeds the cartel level of it, the cement market price in the prefecture will go down. Because there is no reason that firm i deviates from the cartel only in one prefecture, firm i must do the same deviation action in all prefectures at the same time. Due to the deviation of firm i, cement prices in the region must fall below the target levels that the cartel tries to maintain.

Observing the prices fall, vertically integrated firms can react promptly to the defiant firm instead of waiting for one period. They set the input prices of their downstream firms to prices based only on their marginal costs. Namely, they no longer include their shadow prices exactly when they supply to their owned downstream firms as the defiant upstream firm does. By this reaction, the downstream concrete markets turn to be competitive and thus the defiant can obtain less profits that those that would be obtained if there were no reactions of vertically integrated firms.

Formally, the deviant profit is expressed as follows.

$$\begin{aligned}\Pi_{ip}^{DEV} \quad &= \quad \max_{q_{ip}^{nv}} \sum_{p=1}^{P} \left\{ \sum_{m=1}^{M_p} \sum_{d^i=1}^{N_{imp}^{D}} \left\{ \varsigma_{d^i mp} \pi_{d^i mp}^{D,DEV} + (W_{d^i mp} - c_{ip}^{U}) \tau s_{d^i p}^{DEV} (W_p^{DEV}(q_i^{nv})) \right\} \right\} \\ &\quad + \sum_{p=1}^{P} \left\{ (W_p^{DEV}(q_i^{nv}) - c_{ip}^{U}) q_{ip}^{nv} \right\} \qquad (37)\end{aligned}$$

where $\pi_{d^i mp}^{D,DEV}$ and $s_{d^i p}^{DEV}$ are d_i's profit and supply quantity when firm i deviates. The demand curve facing the deviant firm i is defined as

$$W_p^{DEV} = \alpha_p - \beta_p (q_{ip}^{nv} + q_{-ip}^{nv,COL}) \qquad (38)$$

where $q_{-ip}^{nv,COL}$ indicates the amount of quantity supplied by other firms $-i$ when they are complying with the cartel allocation rule and α_p in this demand curve does not include any shadow price because once the deviation of firm i is detected all other upstream firms set input prices based on c_{-ip}^{U} instead of $c_{-ip}^{U,\lambda}$. The deviant firm i faces the demand curve W_p^{DEV} different from that in collusion because vertically integrated downstream firms (of both the deviant and other integrated upstream firms) are supplied at the input prices based on upstream firms' (physical) marginal costs and, as the result of this reaction of vertically integrated firms, the location of the intercept changes to the level of what is realized when all local downstream concrete markets are (Cournot) competitive.

Regarding the collusive profits in the actual and counterfactual market structures, they are calculated in the following way.

First, the level of the actual collusive profit is set the collusive profit in all counterfactual market structures. That is, the level of the total collusive profit is fixed during the experiments. Then, given the total profit, the collusive profit of each upstream firm is determined. The first thing to be determined is Q so that the level is equal to the actual profit $\bar{\Pi}$. Instead of directly choosing supply quantities, changing the shadow prices to achieve the target kevel of the total profit. That is,

$$\min_{\lambda_1,\ldots,\lambda_N} \left(\bar{\Pi} - \Pi^{COL,s}(\lambda_1,\ldots,\lambda_N)\right)^2 \quad s.t.\ \bar{s}_{q_i}^{s} = s_{q_i}\ \ \forall i$$

where s_{q_i} is the share of firm i under scenario s while $\bar{s}_{q_i}^{s}$ is the supply share of firm i in the region that is realized as the result of quantity competition between upstream firms (that is, $\bar{s}_{q_i}^{s}$ is the share of firm i in the punishment phase in (counterfactual) scenario s). The constraint is the reflection of the cartel allocation rule employed actually. Therefore, the assumption is that under any market structure scenario s, the allocation rule is based on the market shares when firms are competing (the shares in the punishment phase) under that scenario.

For simplicity, when calculating the critical discount factors under various market structure scenarios, demand and cost conditions are assumed to remain unchanged. The same demand and cost conditions lasts forever. The reason is that the focus in the present analysis is on the effect of vertical integration on collusive incentive. The analysis of how changes in demand and cost conditions affect cartel incentive has been an important topic in the literature, since Green and Porter (1984) and Rotemberg and Saloner (1986). However, unless these conditions influence firms' vertical integration decision, the assumption is not likely to cause a major problem in the analysis. In fact, cement firms' stakes in downstream firms were almost constant and the number of vertically integrated firms do not change overtime much.

The critical discount factor under the market structure where there is no vertical integration is obtained in the same way. In this environment all downstream firms participate in the input market and all firms receive cement at the market price. Upstream firms are still heterogeneous even though they own no downstream firms. Therefore, firms' marginal costs are different from each other. This heterogeneity between firms requires a quota allocation rule during collusion. The allocation rule employed in this counterfactual market structure is the same allocation rule used in the actual cartel. The cartel allocates quotas to upstream firms, based on market shares realized in competition.

Another issue is that the presence of vertical integration affects the total industry profit that (upstream) firms can obtain. In the model of the current study, there is double marginalization and thus vertical integration can eliminate it. This suggests the possibility that upstream firms can obtain more profit by vertically integrating downstream firms. The total industry supply, the input price, and the industry total profit can depend on whether there is vertical integration or not.[21]

[21]This is the same issue that arises in Normann (2009) when comparing the critical discount factors in different market structures with and without the presence of vertical integration (although his

Therefore, to compare collusion incentives in different market structure scenarios, fix the level of the total collusive profit of upstream firms. Then, for each scenario s, ask how much the minimum discount factor should be in order to maintain the level of the industry profit, and compare different minimum discount factors in different market structures.

8.2 Comparing Critical Discount Factors

In Table 9, the main result in the counterfactual exercise are presented. The critical discount factors of all firms are presented. These values are obtained based on the level of the total profit actually obtained in 1989 by assuming that the demand and supply conditions in that year lasts forever.[22] In Table **??**, the critical discount factors in both the actual and the counterfactual market structure where there is no vertical integration are presented. In the case of the actual environment, the critical discount factor, which is provided by Shinnittetsu is around 0.52. On the other hand, in the counterfactual market structure, the critical discount factor, which is again that of Shinnittetsu, is about 0.58. Therefore, it can be said that vertical integration in the vertically related cement and ready-mixed concrete markets facilitates upstream collusion. This is the first main result that the present paper provides.

However, it is not clear from this exercise that how the vertical relationship between the cement and ready-mixed concrete markets affects upstream firms. As identified in Nocke and White (2007) and Normann (2009), vertical integration has the two contradicting effects on collusion incentive of upstream firms, the punishment effect that, in the punishment phase, vertically integrated upstream firms can gain profits

model is different from the model in this paper).On the other hand, in Nocke and White (2007, 2011), this issue does not happen. The monopoly outcome is realized in both market structure with and without vertical integration.

[22]Exercises using the rest of cartel years produces qualitatively the same results although these results are not presented.

more than those that they would obtain when they are unintegrated and the outlet effect that the deviation profit of a deviator is reduced because the defiant cannot have access to vertically integrated downstream firms. The results presented in Table 9 just show that, overall, the punishment effect overwhelms the outlet effect and thus collusion is facilitated by vertical integration. In the next subsection, these two driving forces are quantified and how these two major driving forces interact is analyzed.

8.3 Mechanism: How Does Vertical Integration Affects Cartel Incentive

The goal here is to understand the mechanism that works to make upstream collusion easier. The main driving forces are the punishment effect and the outlet effect as explained in the present paper repeatedly. The punishment effect is related to the payoff during the punishment phase while the outlet effect is about the profit at the time of deviation. Therefore, how vertical integration influences the punishment profits and the deviation profits should be examined to under stand the underlying mechanism behind the result obtained previously.

In order to quantify changes in these profits in a clear manner, first consider the counterfactual scenario of no vertical integration. Next, consider each upstream firm's vertical integration separately and then analyze the (punishment and outlet) effects of that integration on own and other upstream firms' profits by comparing the critical discount factors in the counterfactual of no vertical integration and those in market structures where each of upstream firms is allowed to own downstream firms that the firm actually owns.

When comparing changes in the punishment and deviation profits in different market structures, one thing that should be taken into account is, again, that vertical integration can influence the profits of all firms. Therefore, the deviation and punishment profits of one firm are defined relative to the collusive profit.[23] That is, the critical discount factor for upstream firm i in (counterfactual) scenario s can be rewritten as the following form:

$$\delta_i^s = \frac{\frac{\Pi_i^{DEV,s}}{\Pi_i^{COL,s}} - 1}{\frac{\Pi_i^{DEV,s}}{\Pi_i^{COL,s}} - \frac{\Pi_i^{PUN,s}}{\Pi_i^{COL,s}}} = \frac{\check{\Pi}_i^{DEV,s} - 1}{\check{\Pi}_i^{DEV,s} - \check{\Pi}_i^{PUN,s}}. \tag{39}$$

The interest here is in quantifying changes in the punishment and deviation profits, which are brought by vertical integration, and the resulting changes in the critical discount factors. Namely, "the marginal effect" that, leaving other upstreams firms unintegrated, only one upstream firm is allowed to own downstream firms that the firm i actually owns is calculated.

In Table 10, "the marginal effects" of all firms but firms that do not own downstream concrete firms in the actual market structure are presented. Changes in the critical discount factor, the deviation and the punishment profit are defined in the following way are shown in Table 10,

$$\Delta\delta_i^s = \delta_i^s - \delta_i^0, \Delta\check{\Pi}_i^{DEV,s} = \check{\Pi}_i^{DEV,s} - \check{\Pi}_i^{DEV,0}, \Delta\check{\Pi}_i^{PUN,s} = \check{\Pi}_i^{PUN,s} - \check{\Pi}_i^{PUN,0} \tag{40}$$

where 0 indicates the market structure where there is no vertical integration and s^j indicates the market structure where only upstream firm j is allowed to own the downstream firms that this firm vertically integrates in the actual market structure.

All results in the table share the same qualitative nature. With respect to the effect on the critical discount factor, firm i's vertical integration increases the firm's critical discount factor while the vertical integration decreases other firms' discount factors.

[23]The sum of profits that upstream firms can obtain during collusion is set the same across different market structures. However, each firm's profit can be different from one market structure scenario to another. The main reason is that market shares can different in different market structures and thus the cartel profits of upstream firms, which is based on the allocation rule based on the market shares in the competitive circumstance in scenario s, can be different from those in another market scenario s even though the sum of firms' collusive profits is set equal across these two different scenarios. The normalization explained here is to adjust these differences arising in different market structures.

The effects of vertical integration on integrated and unintegrated firm works exactly in the direction that the theories predicts. In what follows, changes in the critical discount factors are decomposed into changes in the punishment and deviation profits and this decomposition provides a clearer picture of what is happening when one firm is vertically integrated.

First, the effects of vertical integration of one firm on own and other firms' punishment profits are scrutinized. In all cases, the profits of integrated upstream firms are increased once they are vertically integrated. There are two main reasons. The primary reason is that the downstream markets are not perfectly competitive and thus integrated upstream firms add the profits of their downstream concrete firms to the total profits. Another reason is that, by vertical integration, so-called double marginalization is (at least partly) eliminated and thus integrated downstream firms can become more efficient and as s result upstream firms can gain more profits. The increases in integrated firms' profit in the punishment phase is considered corresponding to the punishment effect identified in Nocke and White (2007).

On the other hand, unintegrated upstream firms' profits are influenced negatively by vertical integration in almost all cases but profits in Aso's vertical integration case and some in other cases. The possible reasons are that, firstly, integrated downstream firms exit from the input market and this reduces the market demand, and, secondly, possible efficiency gain to downstream concrete firms by vertical integration, which is caused by the elimination of double marginalization, reduces the market demand further because independent downstream firms now relatively supply less due to their relative cost disadvantages.

Second, the effects of vertical integration on own and other firms' deviation profits are examined. The main point here is that vertical integration reduces the deviation profits of unintegrated upstream firms in all cases. Reductions in the deviation profits of unintegrated firms caused by vertical integration correspond to the outlet effect in Nocke and White (2007).[24] By vertically integrating downstream firms, integrated downstream firms are supplied by their upstream (cement) firm and exit altogether from the external input (cement) market. Their exits change the shape of the market demand function(s). Because of vertically integrated concrete firms' exits, the market demand curve gets steeper and the size of the market demand shrinks. Therefore, the marginal revenue decreases more quickly than that in the case of no vertical integration. On the other hand, the deviation profits of vertically integrated upstream firms are unchanged or changes are negligible if there is any change.

In sum, in almost all cases, the increased punishment profits for integrated firms raise the critical discount factor of these firms. The depressed deviation profits of unintegrated firms lower the discount needed to support collusion. The two contradicting forces are present.

Table 11 presents the transitions of firms' critical discount factors from the counterfactual market structure of no vertical integration to those in counterfactuals where only firm i vertically integrates downstream firms that the firm actually owns to the actual market structure. From No VI to Own VI, each firm's discount factor increases. Then, transiting from Own VI to Actual VI, facing other firms integrating downstream firms, the critical discount factors are reduced.

Because Shinnittetsu provides the binding incentive constraint, focus on its critical discount factor and see how the critical discount factor changes. First, because this

[24] In fact, the deviation profit includes the effect that, in downstream markets, a vertically integrated firm can respond to the deviation by a non-integrated upstream firm when the integrated firm observes any deviation in the upstream market. Therefore, unintegrated firms' deviation profits are reduced by the integrated firm's reaction in the downstream markets. Normann (2009) calls this the reaction effect.

firm does not own any downstream concrete firms, there is no effect of own vertical integration. Therefore, this firm is just influenced by other firms' integration not influences others' as well as own incentive to collude. The critical discount factor of Shinnittestu changes from around 0.58 to 0.52 with other firms' integration and remains the critical discount factor needed to support the observed level of the total profit.

9 Conclusion

Whether and how vertical integration influences upstream firms' incentive to collude are analyzed using the case of the cartel in the Chugoku region in the Japanese cement industry. The model capturing the two important features of the cement industry, vertical integration and collusion, is constructed and estimated. Based on the model, the effect of vertical integration on upstream firm collusion is measured by quantifying the critical discount factors under the actual market structure and the counterfactual ones where there are no vertical integration. This counterfactual exercise shows that vertical integration decreases the critical discount factor needed to support the same level of the total profit gained by the actual cartel. Therefore, it can be concluded that vertical integration between cement and ready-mixed concrete firms in the Chugoku region facilitated the upstream collusion.

In addition to the analysis of changes in the critical discount factors, the two underlying forces directly influence upstream firms' profits. The punishment effect is the effect that by vertical integration the vertically integrated upstream firm can increase its profit during the punishment phase. Thus, the vertically integrated upstream firm has a higher incentive to deviate. On the other hand, another effect, the outlet effect, is the effect that, by the vertical integration that an upstream firm owns downstream firms, these downstream firms no longer participate in the input market and thus other firms loose the opportunity to sell to them at the time when they deviate. Therefore, by one firm's vertical integration, other upstream firms' deviation profits are reduced and this leads to increase the critical discount factors of these other firms.

These two opposing effects are quantified by using the structural model. The counterfactual exercise shows the outlet effect overwhelms the punishment effect. This is the main mechanism of that vertical integration facilitates upstream collusion.

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Table 1: Market Share Before and After Cartel

	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	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: Vertical Integration: Prefecture

	Concrete Firms	Vertically Integrated Concrete Firms		
Year: 1985		$\leq 50\%$	$> 50\%$	100%
Yamaguchi	77	19	5	2
Okayama	95	19	8	6
Shimane	83	7	2	1
Hiroshima	154	28	8	3
Tottori	34	5	1	1
Region	443	78	24	13

Table 3: Vertical Integration: Cement Firm

Cement Firm	No. Concrete Firms		
Year: 1985	$\leq 50\%$	$> 50\%$	100%
Aso	5	0	0
Mitsubishi	9	5	5
Mitsui	1	1	1
Nihon	18	4	1
Onoda	18	6	2
Nippon Steel	0	0	0
Sumitomo	0	0	0
Tokuyama	13	3	2
Ube	14	5	2

Table 4: Ready-Mix Concrete Demand Estimation Result

	(a)		(b)		(c)	
	IV	OLS	IV	OLS	IV	OLS
Price	-183.689	-1.788	-1.773	-1.721	-17.351	-1.668
	(33.299)	(2.424)	(0.530)	(0.530)	(3.203)	(1.947)
Const. Workers	43.392	6.396	4.132	4.095	10.329	6.275
	(37.154)	(2.705)	(0.388)	(0.388)	(4.112)	(2.499)
Year Effects	Yes		Yes		No	
Prefecture Effects	Yes		No		Yes	
R^2	N.A.	0.967	N.A.	0.944	N.A.	0.932
No. obs.			45			

Table 5: Cement Demand Estimation Result

	(a)		(b)		(c)	
	IV	OLS	IV	OLS	IV	OLS
Price	-47.487	-1.784	-6.521	-6.674	0.517	0.052
	(8.714)	(2.512)	(1.166)	(1.166)	(0.317)	(0.308)
Const. Workers	0.325	0.643	0.368	0.366	0.477	0.517
	(1.307)	(0.377)	(0.024)	(0.024)	(0.274)	(0.266)
Year Effects	Yes		Yes		No	
Prefecture Effects	Yes		No		Yes	
R^2	N.A.	0.967	N.A.	0.944	N.A.	0.932
No. obs.			45			

Table 6: Marginal Cost Function Estimation Result-(1)

	(a-1)	(b-1)	(c-1)	(d-1)
No. SS pref.	-358.742	-358.776	-358.989	-359.230
	(62.791)	(59.128)	(59.564)	(59.573)
No. SS area	-163.114	-150.166	-152.224	-153.220
	(61.362)	(56.715)	(57.175)	(57.246)
Productivity	62.933	-74.610	-73.007	-89.458
	(335.087)	(256.573)	(262.437)	(261.723)
Gasoline Price	-42.647	-42.800	-42.774	-42.761
	(25.368)	(23.892)	(24.068)	(24.071)
Coal Price	-0.110	-0.107	-0.107	-0.106
	(0.165)	(0.155)	(0.156)	(0.156)
Oil6 Price	0.101	0.097	0.097	0.096
	(0.041)	(0.038)	(0.039)	(0.039)
Cartel 1985		2501.807	2359.679	2241.774
		(626.962)	(673.368)	(714.364)
Cartel 1986		2473.924	2405.812	2317.504
		(312.432)	(394.645)	(465.968)
Cartel 1987		3304.226	3190.295	3094.724
		(181.133)	(300.704)	(385.851)
Cartel 1988		2071.295	2117.966	2062.638
		(191.952)	(309.225)	(409.384)
Cartel 1989		1432.877	1448.604	1383.319
		(277.292)	(375.640)	(462.429)
Cartel 1990		909.072	1015.004	928.991
		(239.986)	(340.759)	(437.183)
Cartel×Firm	Yes	No	No	No
Cartel×Share	No	No	Yes	No
Cartel×No.SS	No	No	No	Yes
R2	0.897	0.908	0.907	0.907
No. obs		360		

Table 7: Marginal Cost Function Estimation Result-(2)

	(b-2)	(c-2)	(d-2)
No. SS pref.	-386.710	-387.571	-381.242
	(73.516)	(75.937)	(76.313)
No. SS pref.×Cartel 1985	54.758	34.706	22.803
	(106.517)	(116.752)	(118.871)
No. SS pref.×Cartel 1986	14.795	3.599	-7.037
	(106.657)	(115.964)	(118.228)
No. SS pref.×Cartel 1987	48.140	33.023	25.795
	(107.520)	(117.054)	(119.405)
No. SS pref.×Cartel 1988	56.306	74.077	66.752
	(106.464)	(115.407)	(117.322)
No. SS pref.×Cartel 1989	26.250	33.243	25.061
	(106.502)	(115.362)	(117.275)
No. SS pref.×Cartel 1990	54.052	80.930	66.857
	(104.698)	(113.050)	(115.152)
No. SS area	-150.428	-152.004	-152.613
	(57.192)	(57.634)	(57.730)
Productivity	-72.798	-65.111	-90.419
	(259.230)	(264.881)	(263.891)
Gasoline Price	-42.690	-43.132	-43.116
	(24.407)	(24.639)	(24.665)
Coal Price	-0.107	-0.108	-0.107
	(0.156)	(0.157)	(0.158)
Oil6 Price	0.097	0.097	0.096
	(0.039)	(0.039)	(0.039)
Cartel 1985	2420.386	2337.207	2240.807
	(647.897)	(681.915)	(721.665)
Cartel 1986	2452.560	2401.294	2313.752
	(347.276)	(402.538)	(469.893)
Cartel 1987	3239.267	3177.017	3093.360
	(239.334)	(311.144)	(389.294)
Cartel 1988	1994.845	2077.595	2060.267
	(245.441)	(319.129)	(413.154)
Cartel 1989	1398.296	1434.401	1382.837
	(317.142)	(383.721)	(466.269)
Cartel 1990	833.910	970.350	929.666
	(283.746)	(350.069)	(441.109)
Cartel×Share	No	Yes	No
Cartel×No.SS	No	No	Yes
	0.907	0.905	0.905
No. obs		360	

Table 8: Marginal Cost Function Estimation Result-(3)

	(b-3)	(c-3)	(d-3)
No. SS pref.	-438.758	-433.431	-430.481
	(73.715)	(77.420)	(77.834)
No. SS pref.×Aso× Cartel	41.033	45.442	42.780
	(127.993)	(130.319)	(129.331)
No. SS pref.×Mitsubishi×Cartel	-72.498	-74.290	-77.564
	(134.719)	(135.773)	(137.264)
No. SS pref.×Nihon× Cartel	-100.031	-100.859	-102.886
	(112.450)	(113.543)	(113.918)
No. SS pref.×Onoda× Cartel	176.622	167.247	163.292
	(74.742)	(83.976)	(83.576)
No. SS pref.×Shinnittetsu× Cartel	150.773	163.524	175.135
	(217.865)	(227.625)	(231.917)
No. SS pref.×Sumitomo× Cartel	-36.958	-38.198	-35.844
	(139.797)	(140.870)	(140.988)
No. SS pref.×Tokuyama× Cartel	-8.076	-15.454	-24.131
	(89.826)	(95.547)	(102.520)
No. SS pref.×Ube× Cartel	-212.643	-226.280	-222.579
	(112.108)	(125.917)	(116.881)
No. SS area	-98.211	-101.784	-102.559
	(60.811)	(61.653)	(61.863)
Productivity	39.454	43.395	32.159
	(259.303)	(264.868)	(264.976)
Gasoline Price	-45.406	-45.420	-45.444
	(23.672)	(23.851)	(23.866)
Coal Price	-0.111	-0.111	-0.111
	(0.153)	(0.154)	(0.154)
Oil6 Price	0.102	0.102	0.102
	(0.038)	(0.038)	(0.038)
Cartel 1985	2480.836	2336.310	2284.713
	(628.629)	(680.057)	(729.043)
Cartel 1986	2481.252	2401.277	2348.372
	(323.413)	(412.021)	(491.926)
Cartel 1987	3375.764	3240.228	3181.994
	(206.623)	(326.414)	(417.958)
Cartel 1988	2102.410	2130.260	2107.536
	(212.766)	(333.689)	(443.874)
Cartel 1989	1477.394	1487.612	1460.952
	(291.288)	(395.089)	(491.898)
Cartel 1990	942.534	1030.502	963.985
	(257.403)	(362.869)	(469.040)
Cartel×Share	No	Yes	No
Cartel×No.SS	No	No	Yes
	0.910	0.909	0.909
No. obs		360	

Table 9: Critical Discount Factors

	Actual Market Structure	No VI Market Structure
Aso	0.49	0.55
Mitsubishi	0.41	0.44
Nihon	0.36	0.45
Onoda	0.29	0.40
Shinnittetsu	0.52	0.58
Sumitomo	0.39	0.48
Tokuyama	0.33	0.42
Ube	0.30	0.40

Table 10: The Effects of Vertical Integration

	Aso VI				Mitsubishi VI				Nihon VI			
	$\delta^{s_{Aso}}$	$\triangle\delta$	$\triangle\Pi^{PUN}$	$\triangle\Pi^{DEV}$	$\delta^{s_{Mitsubishi}}$	$\triangle\delta$	$\triangle\Pi^{PUN}$	$\triangle\Pi^{DEV}$	$\delta^{s_{Nihon}}$	$\triangle\delta$	$\triangle\Pi^{PUN}$	$\triangle\Pi^{DEV}$
Aso	0.56	0.01	0.02	0.00	0.52	-0.03	-0.01	-0.07	0.54	-0.01	-0.02	-0.02
Mitsubishi	0.44	0.00	0.00	0.00	0.49	0.05	0.05	0.04	0.42	-0.02	-0.01	-0.02
Nihon	0.44	0.00	0.00	-0.01	0.40	-0.04	-0.01	-0.05	0.46	0.02	0.02	0.01
Onoda	0.39	-0.01	0.00	0.00	0.35	-0.05	0.00	-0.04	0.37	-0.03	-0.01	-0.02
Shinnittetsu	0.58	0.00	0.00	0.00	0.55	-0.02	-0.01	-0.07	0.57	-0.01	-0.02	-0.01
Sumitomo	0.48	0.00	0.00	0.00	0.45	-0.03	-0.01	-0.06	0.46	-0.02	-0.01	-0.02
Tokuyama	0.41	0.00	0.00	0.00	0.37	-0.04	-0.01	-0.05	0.39	-0.03	-0.01	-0.03
Ube	0.39	-0.01	0.00	0.00	0.35	-0.05	0.00	-0.04	0.37	-0.03	-0.01	-0.02
	Onoda VI				Tokuyama VI				Ube VI			
	$\delta^{s_{Onoda}}$	$\triangle\delta$	$\triangle\Pi^{PUN}$	$\triangle\Pi^{DEV}$	$\delta^{s_{Tokuyama}}$	$\triangle\delta$	$\triangle\Pi^{PUN}$	$\triangle\Pi^{DEV}$	$\delta^{s_{Ube}}$	$\triangle\delta$	$\triangle\Pi^{PUN}$	$\triangle\Pi^{DEV}$
Aso	0.54	-0.01	-0.01	-0.03	0.53	-0.02	-0.01	-0.04	0.53	-0.02	-0.02	-0.03
Mitsubishi	0.42	-0.02	-0.01	-0.03	0.42	-0.03	-0.01	-0.04	0.42	-0.03	-0.01	-0.04
Nihon	0.42	-0.02	-0.01	-0.03	0.42	-0.03	-0.01	-0.04	0.42	-0.03	-0.01	-0.04
Onoda	0.40	0.01	0.02	0.00	0.37	-0.03	0.00	-0.03	0.36	-0.03	-0.01	-0.03
Shinnittetsu	0.57	-0.01	-0.01	-0.03	0.56	-0.02	-0.01	-0.05	0.56	-0.01	-0.02	-0.03
Sumitomo	0.46	-0.02	-0.01	-0.03	0.46	-0.02	-0.01	-0.04	0.46	-0.02	-0.01	-0.04
Tokuyama	0.39	-0.02	-0.01	-0.02	0.44	0.02	0.03	0.00	0.39	-0.03	-0.01	-0.03
Ube	0.37	-0.02	-0.01	-0.02	0.37	-0.03	0.00	-0.03	0.41	0.01	0.02	0.00

Table 11: Transition in Critical Discount Factor

	Actual VI	Own VI	No VI
Aso	0.49	0.56	0.55
Mitsubishi	0.41	0.49	0.44
Nihon	0.36	0.46	0.45
Onoda	0.29	0.40	0.40
Shinnittetsu	0.52	N.A.	0.58
Sumitomo	0.39	N.A.	0.48
Tokuyama	0.33	0.44	0.42
Ube	0.30	0.41	0.40