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30 November 2008

Online at https://mpra.ub.uni-muenchen.de/21812/
MPRA Paper No. 21812, posted 05 Apr 2010 02:23 UTC

Horizontal Mergers and Divestment Dynamics in a Sunset Industry*

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November 20, 2008

Abstract

In an oligopolistic market, socially excessive entry takes place because of business-stealing effect which is a gain to the entrant but not to the industry as a whole. Similarly, in a sunset industry with declining demand, now socially excessive capacity cannnot be dissolved because everyone intends to free ride on the reduction of industry supply expected from someone else's divestment. As a result, no firm will divest, even though divestment contributes to the saving on fixed costs. This paper highlights the role of mergers as a device for internalizing the business-stealing effect and thereby promoting divestment, and examines if the merger-induced divestment could improve the total welfare using the case of cement mergers in Japan. A model of divestment based on the Markov perfect equilibrium framework of Ericson and Pakes (1995) is estimated by an asymptotic least squares. Then a counterfactual experiment is conducted to quantify the welfare impact of mergers, and to show that merged firms in fact divested their facilities more and contributed to the improvement of the total welfare despite the reduced consumers surplus.

JEL Classification: L13, L41, L61
Keywords: dynamic discrete game, divestment dynamics, horizontal mergers, sunset industry, cement

*I am grateful to Hiroyuki Odagiri for his constant support and encouragement. Discussions with Hidehiko Ichimura and Tetsushi Murao are invaluable. I also have benefited from the comments of many individuals in the course of this study, among them, Reiko Aoki, Rieko Ishii, Ryo Kambayashi, Daiji Kawaguchi, Hiroshi Ohashi, Ayako Suzuki and Noriyuki Yanagawa. The research has benefited from the financial supports of a grant-in aid (the 21st Century Center of Excellence Project on the Normative Evaluation and Social Choice of Contemporary Economic Systems) from the Ministry of Education and Science, Japan. All errors remain, of course, my own responsibility.

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1 Introduction

In a so-called sunset industry that faces declining demand, the main concern is how to dissolve the excess capacity. From an industry view point, eliminating an excess plant is beneficial as it increases capacity utilization of surviving plants and saves on the fixed cost associated with the plant, such as the cost of minimum labor required to operate and maintain the plant and the rental cost of the land. If this saving on fixed cost outweighs the decrease in consumer welfare, the divestment is socially beneficial as well.

Yet, such divestment may not voluntarily take place in an oligopolistic industry for a reason exactly opposite to the excess entry theorem (Mankiw and Whinston (1986) and Suzumura and Kiyono (1987)). According to this theorem, the presence of fixed costs induce entry of socially too many firms. The reason is the presence of business-stealing effect: the entrant gains sufficient demand partly by stealing business from incumbent firms. It is a gain to the entrant but not to the industry and, in consequence, the entry may be socially excessive.

In a sunset industry, excess capacity may not be divested for exactly the reverse reason: each firm is unwilling to divest because the gain is partly (or possibly mostly) captured by the rival firms. In other words, every firm intends to free-ride on the reduction of industry supply expected from someone else's divestment. The end result is that no firm will divest, prolonging the excess capacity situation.[1]

A merger can internalize this business-stealing effect. In a horizontal merger between A and B, post-merger A should have less incentive to reduce price and promote sales because its stealing business from B is now internalized, bringing in no gain to the merged firm. In consequence, the merged firm will reduce promotion efforts, even-

[1] An interesting point is that welfare loss due to free entry declines as the socially optimal number of entrants increases (Mankiw and Whinston (1986, example 1)). This implies that since the socially desirable level of capacity decreases with demand decline the welfare is increasingly impaired by the excessive capacity in declining industries.

tually reducing the market share (Odagiri (2008)). Also, merger internalizes the effect of capacity expansion on market price; that is, an output expansion caused by A's investment hurts B's profits, thereby reducing the contributions to the merged firm's profits. In consequence, a merged firm has less incentive to engage in a capacity expansion race. Berry and Pakes (1993) investigated this effect of merger using a dynamic oligopoly model.

A merged firm can internalize the gain from divestment because B's gain from A's divestment is now part of the firm's gain. Therefore, a merger can promote divestment, contributing to the saving of fixed cost and the receipt of scrap value from divestment. Of course, the merger may also cause the price to rise and, from the social viewpoint, the resulting loss of consumer surplus must be balanced against the saved fixed cost and the received scrap value.

I highlight the role of mergers as a device for alleviating the inefficiency of divestment and investigate whether the merger-induced divestment can improve the total welfare. For this purpose, the case of cement mergers in Japan is studied. The Japanese cement industry provides a good example for studying the effect of merger in a decline period. The industry is interpreted as a sunset industry in the sense that it has faced the downward trend in demand. Since the burst of the bubble economy public and private investment in construction, it is indicative for the cement consumption, has decreased over the 1990s and settles in the level of 30 years ago. As demand has shrunk, the industry has been forced to contract its size and become more efficient to survive in such severe circumstance. In the middle of phase of decline, four mergers and one acquisition took place. After mergers, the industry has reduced its capital assets and contracted along with the decline of demand. Whether this contraction induced by consolidation could enhance the efficiency and improve the welfare is the main interest.

To evaluate the welfare effect of horizontal mergers, a theoretical model to capture the industry dynamics featured by divestment and negative shock in demand is constructed building on the Markov perfect equilibrium framework of Ericson and Pakes.[2] The underlying parameters of the model governing divestment dynamics is estimated by the recently developed econometric method, the asymptotic least squares coupled with forward simulation (Pesendorfer and Shmidt-Dengler (2008) and Bajari, Benkard and Levin (2007)). With parameters estimates, a simulation exercise is conducted to explore what it would have happened to the cement industry if no merger had taken place.

The contribution of the paper is twofold. Firstly, my main interest is in a declining industry. Since the early works by Ghemawat and Nalebuff (1985) and Fudenberg and Tirole (1986), surprisingly few studies have been made on declining industries, despite the fact that almost all developed nations have declining sectors and how to promote capacity reduction in such sector is a pressing policy issue. Secondly, horizontal mergers are evaluated form a dynamic perspective. In particular, the focus is on the effect of mergers on divestment behavior and on its welfare consequence. Since Stigler (1968) emphasized on the importance of a dynamic perspective on merger analysis, many researchers have tried to incorporate his intention into the model. Particularly, in recent years several theoretical models have been proposed, some of which are Berry and Pakes (1993), Gowrisankaran (1999), Pesendorfer (2005) and Choeng and Judd (2006). But, in spite of blossoming of theoretical and numerical studies, empirical analyses on merger from a dynamic perspective have not been conducted except only a few papers. To the best of my knowledge the present paper is one of the first attempts to examine the implications of mergers employing a fully dynamic divestment model.[3]

In addition to the impacts on academic world, this paper also has an important

[2] In recent years Ericson and Pakes model is extensively used in both theoretical and empirical Industrial Organization. See Draszelski and Pakes (2006) for applications.

[3] Pesendorfer (2003) develops a simple investment model reflecting competition in the US paper industry. While his model is inherently static one, it succeeds to capture the dynamic aspect of investment decisions in the industry. Recently, Myojo and Ohashi (2008) investigate the merger in the Japanese steel industry with a dynamic investment model.

policy implication. US horizontal merger guidelines states that "the agencies consider merger-specific, cognizable reductions in fixed costs, even if they cannot be expected to result in direct short-term, procompetitive price effects because consumers may benefit from them over the longer term even if not immediately".[4] My study below will show that a horizontal merger can facilitate divestment and thereby reduce fixed cost. It will also show that this fixed cost savings plus sell-off values may be a substantial contribution to the total surplus. According to the US guidelines, such a merger will not be accepted because, even in long run, price reduction is not expected to take place. However, if the total surplus is to be the welfare criterion, the merger possibly had better be accepted. My analysis, therefore, will provide a critical policy question to the competition policy authority.

The paper is organized as follows. Section 2 provides brief information of cement industry. Section 3 presents a theoretical model to capture the competition in the cement industry. It allows for divestment as well as a traditional quantity setting competition. In section 4, structural parameters of the model are estimated by the two step method. Section 5 conducts a simulation experiment exploring what have happened to the cement industry if any mergers had not taken place.

2 The Cement Industry in Japan

The Japanese cement industry provides a good example for studying mergers in a decline period. Figure 1 shows the movements of cement consumption and governmental and private investments in construction. Cement is the key gradient of concrete, which is used as a fimm material, such as skyscrapers, roadways, railways, airports, seaports, and other arteries of society. Therefore, the cement consumption largely depends on construction investment in both private and public sectors as depicted in Figure 1.

[4] US department of Justice and Federal Trade Commission, "Commentary on the Horizontal Merger Guidelines,", March 2006, p.58.

The cement consumption had steadily increased during the 1980s and expanded until burst of the bubble economy. Thereafter it has been declining as the construction investments have been shrinking and in recent years settles down in around 70% level of its peak, which is the same amount of 30 years ago.

As the demand has shrunk, the cement industry has been contracting its size to survive in such severe circumstance. In Figure 2 the remarkable reduction of cement distribution facilities is observed during the period. The facility connecting cement plants to local customers, 'service station', plays the key role in the cement delivery flow. Once cement produced in a plant, usually it is delivered by sea to service stations in regional markets.[5] Cement service stations are scattering mainly at sea front area in a regional market. In an individual region a cement firm carries its product from service stations to its local consumers by truck. This stage of the transportation from a service station to consumers is called as 'secondary stage delivery' whereas the transportation from a plant to a service station is 'primary stage delivery'. The transportation cost of the secondary stage is high enough to prevent a firm from delivering its product to customers far from a service station. To avoid long haul carriages, the cement firms set up several facilities within a regional market. Through its effect on the transportation cost, the number of service stations in a market determines firm's supply capacity substantially.[6]

Although it contributes to the expansion of its supply, operating a service station is also a substantial burden on a cement firm since variable and fixed costs related to the operation are not negligible. For example, these costs include cost for keeping up a

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[5]Cement plants locate at areas where lime stone is reserved in abundantly, e.g. Chugoku, Hokkaido and Kyushu. Plants in such areas account for an enormous proportion of cement production in Japan. As explained in the later section, there are eleven regional markets in Japan, Hokkaido, Tohoku, North and South Kanto, Hokuriku, Tokai, Kansai, Chugoku, Shikoku, Kyushu and Okinawa. Cement firms are doing their business in some of or all of these regions and have a local headquarter in the regions.

[6]Cement firms are required to bring its product to not only concrete plants of its customers but also to customers' construction sites. Therefore they face uncertainty on the distance from their service stations to the construction sites. Due to this nature of the cement delivery, it is likely to be advantageous for them to have several distribution facilities in a regional market.

fleet of cement tracks for delivery, the primary stage delivery cost, which is proportional to the number of service stations, and a cost of minimum labor requirement for the operation. As the demand has declined, pressure for facilities to be scrapped has been increasingly created. In fact, it was said that the main concern was how to eliminate its abundant facilities and to reduce the fixed costs to restore profitability. This motive for reducing their excessive facilities as well as achieving some efficiency gains led the industry to reorganization.

2.1 Mergers

In the 1990s, the Japanese cement industry has experienced its market reorganization. Particularly the mergers listed below accelerated the market consolidation dramatically.[7]

- 1994 Onoda Cement + Chichibu Cement → Chihibu-Onoda Cement
- 1994 Sumitomo Cement + Osaka Cement → Sumitomo-Osaka Cement
- 1998 Chihibu-Onoda Cement + Nihon Cement → Taihaiyo Cement
- 1998 Mitsubishi Cement + Ube Cement → Ube-Mitsubishi Cement[8]

All four mergers reduced the number of firms operating in a regional market because they involved firms operating in all regional markets. Table 1 indicates that it was reduced from nine to six on an average. Not only did the mergers reduce the number of firms, they also changed the concentration ratio largely. Table 2 reveals that three firm concentration ratio (CR3) in terms of service stations rose in nearly 20% after 1994 mergers and exceeded 80% in an average by the second mergers.

[7] Although one acquisition, Mitsubishi's acquisition of Tohokukaihatsu, took place, its did not have any impact on a regional competition because these two firms were operating in different markets each other.

[8] Ube-Mitsubishi Cement is a merging sales company of Ube Cement and Mitsubishi Cement. They have not merged their production divisions. But this paper deal with it as a merging firm because we focus on cement firm's supply behavior in a market, not on a production.

Price is also an important figure in evaluating the effect of mergers. Figure 4 displays the price movement before and after four mergers. During the period, despite experiencing four big mergers, the cement industry has continued to get the price down. Although this finding may be a little bit surprising, this price trend is complicated by the downward shock in demand. Thus, in examining the price changes, it is necessary to take such exogenous factor into account and to separate it off from the influence of the mergers.

As mentioned above, substantial reductions of distribution facilities have been observed after the mergers. Figure 3 indicates that the steady decline in the total number of service stations and also shows that the most part of the reductions by the merged firms. The merged firms have scrapped about 25% of their facilities. On the other hand, non-merged firms have reduced nearly 15% of their service stations. This fact may suggest that the mergers affected firms' incentive for holding facilities and prompted the reduction of distribution facilities.

The above facts regarding the demand declining and the capacity removals will imply the importance of evaluating mergers with an explicit consideration about a constantly changing environment. Ignorance of such dynamic aspects of the industry caused by endogenous and exogenous factors must lead to an erroneous implication to mergers in a declining period.

3 Data

Of particular interest in this research is to analyze how the mergers affected the incentive for capacity removals and whether the merger induced divestment improved the total welfare. For this purpose, the data including only *after* the merger wave, 1998-2006, is used. All of the data are collected from Cement year book 1998-2006. Cement year book is published annually by Japan cement association and provides useful information on firm-region level activities, distribution facilities and quantities sold, cement prices, and public and private investments, which is a demand proxy variable.

According to Japan cement association, the cement market is divided into eleven regional markets, Hokkaido, Tohoku, North and South Kanto, Hokuriku, Tokai, Kansai, Chugoku, Shikoku, Kyushu and Okinawa. Among these regional markets, six regional markets, Hokkaido, Tohoku, Tokai, Kinki, Chugoku, Shikoku, are selected as the sample for this research. Three markets, Hokuriku, Koshin-etsu and Okinawa, are excluded due to the lack of price information. Further two markets, Kanto and Kyushu, are also excluded because the average sizes of service stations in these two markets are very different from other markets.[9]

Table 4 summarizes the data. The upper three rows are the regional market level data. Price is the annual average price in each regional market. Cement Consumption is the total amount of annual consumption in an individual regional market. Construction Investment is the proxy variable for the industrywide demand shifter and it is the sum of private and governmental investments in construction. Three variables in the lower half of the table are the firm level data in each regional market. Supply Quantity is the amount of quantities sold by a firm. No.SS is the number of service stations of a firm, and Divestment is also the number of service stations scrapped by a firm.

To make the estimation procedure manageable, I focus on the activities of the largest five or four firms in an individual market. Due to this, relatively small firms are excluded. However the total supply of these selected large firms covers at least 85 percent of total supply in a region and the average coverage is above 95 percent of total supply in a region during the sample period. So this data manipulation will not have any substantial impact on the analysis.

[9] In Kanto region, the size of a service station is quite large, but the number of SSs is small. On the other hand, in Kyusyu region, the situation is completely opposite. We do not know the reason, but it implies that the value of a SS in the two regions is far different from that of SS in other regions.

4 Model

To evaluate the welfare effect of the mergers, it is necessary to develop a theoretical model that captures features of the cement industry. As previously noted, an individual cement market is localized and concentrated, and product is regarded as a homogeneous good. Further the industry has been facing the downward trend in its demand and, as the demand has shrunk, the cement firms have been forced to reduce their distribution facilities, service stations (hereafter SSs), to remain profitable. Although by selling off SSs the firms can receive scrap value and save fixed costs, the part of its business is stolen by competitors unless a scrapped distribution facility is completely abundant. Therefore strategic interaction between cement firms in a regional market is one of the key determinants of their divestment decision process. In addition, it it natural to consider that scrapping a SS also has a dynamic impact on future market configurations. It changes not only the number of own SSs in the subsequent periods but also the entire state of the market through strategic interactions. As a result, the stream of future cash flows depends on the facility removal decision in the current period. Therefore, in deciding whether scrapping some of SSs or not, a cement firm will contemplate the influence of its action on future market structure.

With these characteristics of the industry, the competition in homogeneous product market, the dynamic divestment decision and the exogenous demand shift, a model of oligopolistic competition in a dynamic environment is needed. Ericson and Pakes (1995) provide an elegant framework of dynamic oligopoly which is designed to capture the industry dynamics with heterogeneous firms. Building on their Markov perfect equilibrium framework, I construct a simple model of dynamic divestment decision process.[10]

In the model each firm is characterized by only its state variable and also a regional

[10] The model can be regarded as a simplified model of Besanko, Daraszelski, Lu and Sattherthwaite (2008), which allows for both investment and divestment actions.

market is completely described by a state vector consisting of firms' state variables and industrywide exogenous demand shock. At the beginning of each period firms decide simultaneously whether scrapping capacity or not, and if so, choose the number of SSs scrapped given their beliefs on future market configurations. Following the divestment decisions, the product market competition takes place. Given their facilities, demand level and competitors' strategies, firms compete each other in quantity.At the end of the period each firm obtains profit as a result of product market competition and receives scrap value(s) if it reduced some of its SSs, and the state variables evolves following the realizations of divestments and demand shock.

In contrast to Ericson and Pakes (1995) in which investment is a continuos variable (but the state variables are still discrete), I have to consider a discrete divestment action since the facility, SS, is indivisible. This discrete nature of divestment behaviors may cause the existence problem of an equilibrium of the model (Draszelski and Satterthwaite (2007)). To avoid such problem a random scrap value is introduced into the model, and it is assume that before firms taking any actions they observe their scrap value privately. Other than insuring the existence of an equilibrium, introducing a privately known scrap value is justified in terms of at least the following two points. First, in the real world, a firm would face uncertainty about competitors' actions since it can not know other competitors' cash flows exactly. Introducing a privately known scrap value reflects this uncertainty. Another reason is that a dynamic stochastic game with incomplete information can be estimated by recently developed econometric methods by Aguirregabiria and Mira (2007), Bajari, Benkard and Levin (2007), Pakes, Ostrovsky and Berry (2007), and Pesendorfer and Schidt-Dengler (2008). With the advancements in econometrics of dynamic game models, underlying parameters of the model can be recovered from the observed data. Once underlying parameters at hand, a counterfactual simulation can be conducted to evaluate the mergers. For these reasons, I describe the dynamic competition in the cement industry as a dynamic discrete game with incomplete information.

States As just noted, a regional cement market is assumed to be completely characterized by a payoff relevant state vector. The list of state variables includes each firm's state variable and an industrywide demand shock. The firm state variable are the number of its SSs in the region. The number of SSs determines firm's supply capacity and therefore affects its profit substantially. A demand shock is also payoff relevant because profit of each firm depends on the demand condition of each period. We define the state vector as

$$\omega_t = (s_{1t}, ..., s_{Nt}, z_t) \tag{1}$$

where state variable s_{it} represents firm i's number of SSs in the regional market and z_t is the demand shifter. A subscript r labeling a regional market is dropped for expositional simplicity.

The movement of the state vector from current to next period depends on firms' decisions and the exogenous demand movement. The movements of these states are weakly unidirectional. That is, the state variables can only move to a lower state or remain in the current state. This reflects the fact that the cement industry have faced a downward shock in demand and firms have continued to reduce their facilities as the demand declines. Therefore, an upward move in the state variables need not be considered.[11]

The number of SSs in the next period depends on whether firm divests its facilities and how many it scraps. If firm i scraped d_{it} of it's own SSs, the number of SSs in the

[11] The unidirectional movement of the state variables can often lead to the uniqueness of equilibria of the model, like the case of Cabral and Riodan (1994) or Besanko, Draszelski, Lu and Satterthwaite (2008).

next period is

$$s_{it+1} = s_{it} - d_{it} \tag{2}$$

where s_{it+1} is the number of SSs in next period and d_{it} is the number of SSs scrapped in the current period. This facility adjustment is assumed to take one year and depreciation is not considered. The demand shock moves stochastically to a lower demand level or remains in the current level. In contrast to firm's capital stock, it is assumed to evolve exogenously.

Timing All actions are made as a function of the state variables in the beginning of the period. Each firm makes divestment decision at first given its beliefs on other firms' strategies and on future market condition after observing the demand shock and knowing scrap value of its SS privately. Once the divestment decisions are made, firms compete against each other in the product market . At the end of the period, each firm obtains profit resulting from the product market competition and receives scrap value if it scraped some of its SSs. Then the state variables evolves following the actions and the realization of demand shock.

The sequence of events in each period unfolds as follows:

1. Each firm knows its scrap value privately and observes the demand level at the current state.
2. Each firm makes the divestment decision (decides the number of SSs in the next period).
3. Given the current state variables (the number of SSs and the demand level), firms compete each other over quantities.
4. Each firm obtains the per-period profit and receives scrap value(s) if it sold off some of its SSs.

5. The state vector evolves as the divestments are completed and the demand moves.

Cashflow The per-period cashflow is composed by two terms, product market profit and scrap value. Profit from product market is the result of quantity competition given the current market configuration. Each firm receives scrap value(s) if it scraped it's own SSs. Thus a per-period cashflow of firm i at state ω_t can be written by

$$\pi_{it}(\omega_t) = u_{it}(\omega_t) + \phi_{it} * d_{it}. \tag{3}$$

$u_{it}(\omega)$ is a product market profit including fixed cost f_{ss} and ϕ_{it} is scrap value. The main part of scrap value is the sell-off value of land and the fixed cost is the cost of minimum labor and equipments required to operate a SS, e.g. a fleet of cement trucks. Privately known scrap value ϕ_{it} is assumed to follow the normal distribution with mean μ and variance k^2 and to be independent across firms and periods.

Product market competition and profit Given the current state ω_t, firms compete each other in quantity in the product market. The product market profit function is written by

$$u_{it}(\omega_t) = P(Q_t)q_{it} - C(s_{it}, q_{it}) \tag{4}$$

where $P(Q_t)$ is the inverse demand function, $C(s_{it}, q_{it})$ is the cost function depending on the number of SSs, s_{it}, and the quantity supplied, q_{it}. The inverse demand function with constant price elasticity is assumed:

$$P(Q_t) = A_0 Q_t^{\alpha_1} z_t^{\alpha_2} \tag{5}$$

where z_t is a demand shock and is treated as a state variable and A_0 contains a time invariant market specific effect on price.

As explained previously, the transportation cost is assumed to be influenced by the number of SSs hold in a market and, as a result, the amount of supply quantity is also affected by it. Therefore firm i's cost function is expressed as a function of its own state variable s_{it} and quantity q_{it}:

$$C(s_{it}, q_{it}) = A_3 s_{it}^{\alpha_4} q_{it} + f_{ss} s_{it} \tag{6}$$

where A_3 includes a region specific shift parameter and it is assumed constant over time. If α_4 is negative (and in fact it is estimated to be negative in the later section), firm i faces the lower marginal cost of transporting its product to customer as it has the larger number of SSs. The lower marginal cost can be achieved mainly since if a firm keeps the larger number of facilities in a region it can manage cement distribution among facilities and avoid costly long haul carriages. f_{ss} is fixed cost and is proportional to the own state variable s_{it}.

Cournot Nash equilibrium in the product market competition is assumed and the outcome itself has no effect on actions from the current period on. By this so-called 'static-dynamic' breakdown assumption, the per-period profit $u_i(\omega)$ can be computed off the algorithm for solving an equilibrium of the model.[12]

Divestment decision and Value function Now I turn into the decision process of removing facilities. Since the divestment decision in the current period affects market structure in the subsequent periods, it can change the stream of future cash flows. Therefore it is natural to assume that firm's divestment decision has the dynamic nature in contrast to the determination of per-period supply quantity and each firm thus takes its facility reduction decision to maximize the discounted expected future cash flows given its beliefs on competitors' actions and the future market conditions.

[12]In other words, the per-period profit function can be treated as a primitive of the model when solving an equilibrium.

To analyze the decision process in such a complex environment, the strategy space is focused on Markov class (Maskin and Tirole (2001)). In Markov strategies the past influences the current actions only though its effect on the current state variables that summarizes the direct effect of the past actions on the current state. Formally, the Markov strategy mapping state variables and a private shock to actions is expressed as $d_i = d(\omega, \phi_i), d_i \in D_i$. In this study an action $d_i \in D_i$ is discrete due to the indivisible nature of SS.

The firm's decision problem is to choose the number of SS scrapped at the current period with consideration about it's effect on the future cash flow stream given its belief on future market configurations. Given actions follow a Markov strategy, the optimal divestment decision of firm i at state ω is defined recursively by the solution to the following Bellman equation:

$$\begin{aligned} V_i(\omega, \phi_i; \sigma_i) &= u_i(s_i, s_{-i}, z) \\ &+ \max_{d_i \in D_i} \left\{ d_i \phi_i + \beta \sum_{s'_{-i}, z'} V_i(s_i - d_i, s'_{-i}, z'; \sigma_i) g_i(s'_{-i}, s_i, s_{-i}, z) q(z'|z) \right\} \end{aligned} \tag{7}$$

where β is discount factor and the summation is taken over all of the one-period reachable states of other firms and demand from the current state. $V(s'_i, s'_{-i}, z')_i$ is firm i's expected value function at a state ω before observing a scrap value and it is defined as $V_i(s'_i, s'_{-i}, z) = \int V_i(s_i - d_i, s'_{-i}, z', \phi'_i) dF(\phi'_i)$. For expositional convenience, the components of the state vector, (s_i, s_{-i}, z), are explicitly expressed. $g_i(s'_{-i}, s_i, s_{-i}, z)$ is firm i's perceived state transition probabilities from the current state, (s_i, s_{-i}, z), to the next state of competitors, s'_{-i}. It can be written by the product of the firm's beliefs on competitors' actions d_{-i} at state ω:

$$g_i(s'_{-i}, s_i, s_{-i}, z) = \prod_{-i} \sigma_i(d_{-i}|s_i, s_{-i}, z). \tag{8}$$

where $s'_{-i} = s_{-i} - d_{-i}$. $q(z'|z)$ is the transition probability of the demand shock shifting from the current demand level to the next state.

To express the decision rule in a simpler way, let $W(d_i|\omega)$ be the weighted average of the expected value functions when firm i takes an action d_i at the current state,

$$W(d_i|\omega) = \sum_{s'_{-i}, z'} V_i(s_i - d_i, s'_{-i}, z'; \sigma_i) g_i(s'_{-i}, d_{-i}, s_i, s_{-i}, z) q(z'|z). \tag{9}$$

At the beginning of each period firm i knows scrap value of it's SS privately, and it chooses the number of SSs scrapped in that period comparing the scrap value with the differentials in the future expected value functions by the reductions of its facilities. This optimal decision problem is expressed in the following way:

$$d_i = \begin{cases} 0 \quad \text{if} \;\; \beta\big(W(0|\omega) - W(1|\omega)\big) \geq \phi_i \\ a(1 \leq a < \bar{a}) \quad \text{if} \;\; \beta\big(W(a-1|\omega) - W(a|s)\big) < \phi_i \leq \beta\big(W(a|\omega) - W(a+1|\omega)\big) \\ \bar{a} \quad \text{if} \;\; \beta\big(W(\bar{a}|\omega) - W(\bar{a}-1|\omega)\big) > \phi_i. \end{cases} \tag{10}$$

A difference between $W(\cdot|\omega)$s denotes a cutoff point. If firm i received scrap value below the first cutoff point, it does not do anything and keeps the current facilities in the next period. Otherwise, divestment is done according to the above decision rule (10). For example, if its scrap value was beyond the first cutoff point but not above the second point, firm i would reduce only one SS. Or, if it fall between the second cutoff point and the third, firm i scraps two SSs. Thus the divestment decision rule maximizing the future profit is expressed as the cutoff strategy depending on the realization of private scrap value and the value function differentials.

The cutoff decision rule can be expressed alternatively by the probability that each action can be taken. Let $P(d_i|\omega)$ be the probability that firm i divests d_i unit of it's own SSs in the state ω:

$$P(d_i|\omega) = \begin{cases} \int_{-\infty}^{\beta((W(0|\omega)-W(1|\omega))} dF(\phi_i) \text{ if } d_i = 0 \\ \int_{\beta(W(d_i-1|\omega)-W(d_i|\omega))}^{\beta(W(d_i|\omega)-W(d_i+1|\omega))} dF(\phi_i) \text{ if } 1 \leq d_i < \bar{a} \\ \int_{\beta(W(d_i|\omega)-W(d_i-1|\omega))}^{\infty} dF(\phi_i) \text{ if } d_i = \bar{a}. \end{cases} \tag{11}$$

The last remaining component of the model is the expected value function $V_i(s_i, s_{-i}, z)$. It can be obtained by integrating over ϕ_i on both sides of (7).

$$V_i(\omega;\sigma_i) = u_i(s_i, s_{-i}, z) + \sum_{d_i} P(d_i|s_i, s_{-i}, z)\Big\{d_i E[\phi_i|s_i, s_{-i}, z] + \beta W(d_i|s_i, s_{-i}, z)\Big\} \tag{12}$$

$E[\phi_i|\omega]$ is the expectation of scrap value conditioning on scraping d_i of SSs.[13] Once the expected value functions are at hand, firms i's optimal choice can be obtained by (10) or (11).

The expression of (12) is very useful. By integrating out scrap value, it is possible to eliminate the continuous state variable ϕ_i from the state variables vector. Consequently the computational disadvantage due to the introduction of private information disappears (Draszelski and Satterthwaite (2007)).

Equilibrium The equilibrium concept of this model is Markov perfect Nash. A Markov perfect Nash equilirium (MPNE) insures that at each state each firm chooses optimal action given its beliefs on future market structure and those beliefs are consistent with the actions of other competitors.

[13]The expected scrap value of SS conditional on scrapping d_i of SSs is calculated by

$$where E[\phi_i|\omega] = \begin{cases} [P(d_i|\omega)]^{-1} \int \phi \cdot \mathbf{1}[\beta(W_{d_i-1} - W_{d_i}|) < \phi_i \leq \beta(W_{d_i} - W_{d_i+1})] dF(\phi_i) \text{ if } 0 < d_i < \bar{a} \\ [P(d_i|\omega)]^{-1} \int \phi \cdot \mathbf{1}[W_{d_i} - W_{d_i-1} > \phi] dF(\phi_i) \text{ if } d_i = \bar{a} \end{cases},$$

where W_{d_i} is $W(d_i|\omega)$.

Following Pesendorfer and Shmidt-Dengler (2008), I set the equilibrium system of this model. The choice probabilities of (11) can be described by the equation system $\mathbf{P} = \boldsymbol{\Psi}(\mathbf{V}(\sigma))$. $\mathbf{P}$ is a vector of the optimal choice probabilities for all states and firms, and $\mathbf{V}$ is a vector of the expected value functions and it is the function of σ, which is a vector of firms' beliefs on competitors' actions. $\boldsymbol{\Psi}$ is a function that characterizes the best responses. Since in equilibrium the firm's beliefs are consistent with the choice probabilities, an MPNE can be characterized as a fixed-point in the equation system:

$$\mathbf{P}^* = \boldsymbol{\Psi}(\mathbf{V}(\mathbf{P}^*)). \tag{13}$$

As stated in Proposition 1 in Pesendorfer and Shmidt-Dengler (2008), the equation system (13) is a necessary and also a sufficient condition for an MPNE. Not only does it characterize the set of equilibria, it can be exploited to recover the underlying parameters of the model governing the facility reduction decisions.

5 Estimation

The goal in this section is to estimate the underlying parameters governing dynamics in the theoretical model. Target parameters can be divided in two types: static parameters and dynamic parameters. Static parameters govern the static competition and determine the per-period profit. These parameters including demand and cost function parameters can be recovered without any difficulties by commonly used estimation techniques. On the other hand, since dynamic parameters have to be inferred from firm's dynamic decision process, the estimation of these parameters involving computing value functions many times is often a computationally tough task (see Rust (1987, 1994), Pakes (1986) and Pakes (1994)).

However, in recent years, innovative econometric techniques which can settle the computational problem in estimating dynamic decision models have been developed

(Aguirregabiria and Mira (2007), Bajari, Benkard and Levin (2007), Pakes, Ostrovsky (2007) and Berry (2007) and Pesendorfer and Schidt-Dengler (2008)). Those estimation methods can avoid or mitigate the time-consuming value function computations by exploiting observed (equilibrium) actions. In this paper to estimate the structural parameters I use an asymptotic least squares proposed by Pesendorfer and Shmidt-Dengler (2008) and implement their estimator coupled with forward simulation technique by Bajari, Benkard and Levin (2007). The basic procedures of the estimation are the following two steps. 1) Under the assumptions that the observed data are generated from a single MPNE profile and that the equilibrium selection mechanism is same across all regional markets, the policy functions and the equilibrium beliefs can be recovered, and the value functions can be approximated by averaging many simulated paths generated by the estimated policy functions.[14] 2) The parameters of interest are set to match the observed choice probabilities at each state with the outcomes predicted from the theoretical model.

Let $V_i(\omega|\mathbf{d}(\omega,\phi);\theta)$ be the expected value function of firm i at state ω under the parameter values of θ given firms following the Markov strategy $\mathbf{d}$. Then it can be defined as the sum of future values of profit $\pi_i(\omega_t, \mathbf{d}(\omega_t,\phi_t), \phi_{it};\theta)$ from starting state ω:

$$V_i(\omega; \mathbf{d}(\omega,\phi), \theta) = E\Bigg[\sum_{t=0}^{\infty} \beta^t \pi_i(\omega_t, \mathbf{d}(\omega_t,\phi_t), \phi_{it};\theta)\big|\omega_0 = \omega; \theta\Bigg]. \tag{14}$$

The expectations over the current and future private values and the future states. Forward simulation approximates the above expected value function by averaging many simulated paths of infinite future profit streams starting from ω. As will be explained, the optimal choice rule at each state $\mathbf{d}(\omega,\phi)$ can be expressed by a function of the choice probabilities $\mathbf{P}(\mathbf{d}|\omega)$ and therefore the value functions can be also a function of

[14] See Berry and Tamer (2006) for detailed discussions on the issues of multiple equilibria and the equilibrium selection mechanisms and their critique on the common equilibrium assumption across different markets.

the choice probabilities. That is, with estimates of the choice probabilities and forward simulation, the equilibrium value functions can be estimated as $\hat{\mathbf{V}}(\hat{\mathbf{P}}^*;\theta)$.

The asymptotic least squares principle consists of estimating parameters of interest θ by forcing the equilibrium constraints

$$\mathbf{g}(\hat{\mathbf{V}}(\hat{\mathbf{P}}^*),\theta) = \hat{\mathbf{P}}^* - \mathbf{\Psi}(\hat{\mathbf{V}}(\hat{\mathbf{P}}^*;\theta),\theta) = \mathbf{0} \tag{15}$$

to be satisfied approximately (Pesendorfer and Shmidt-Dengler (2008)). $\hat{\mathbf{P}}^*$ is a vector of the observed probabilities and $\mathbf{\Psi}(\cdot)$ is a vector of the equilibrium choice probabilities predicted by the model. The relationship between the parameters of interest and auxiliary parameters $\mathbf{g}(\cdot)$ is called as an asymptotic model. The asymptotic least squares problem is to find parameters minimizing the distance of $\mathbf{g}(\cdot)$ to zero in a metric of a given weighting matrix.

5.1 First Step Estimation

In the first step demand function and cost function is estimated to recover parameters governing the quantity competition and obtain the per-period profit function. Then the equilibrium policy function can be estimated from the observed equilibrium play at each state. With these estimates, the equilibrium value function can be calculated by averaging many simulated equilibrium paths.

Demand Function To estimate demand function, the region-year observations of quantities sold and prices are used. The static demand function at each regional market is defined by

$$log(Q_t) = \alpha_0 - \alpha_1 log(P_t) + \alpha_2 log(z_t) + \epsilon_t, \tag{16}$$

where P_t is price at time t, Q_t is quantity sold, and z_t is private and public spending in construction.[15] I estimate the demand function parameter values by 2SLS. Instruments are one period lagged endogenous variables. The transition probability of demand shifter z_t should be also estimated. But, unfortunately, due to the data limitation this is impossible. Therefore, we assume that it moves to a lower state from the current state with probability 0.7 and stays forever once it reaches the demand level of 2006.

Cost Function Since cost side variables are proprietary to firms and inherently difficult to obtain, the straightforward estimation like the demand function can not be done. Therefore, to estimate cost function, an assumption on the product market competition has to be imposed.[16] The equilibrium concept used here is Cournot Nash. In Cournot game firms determine their quantities to maximize the per-period profit function given other firms' quantities. The predicted marginal costs are obtained form the set of first order conditions of firms in the market:

$$mc_{it} = P_t(Q_t) + \frac{\partial P_t(Q_t)}{\partial q_{it}} q_{it}. \tag{17}$$

As demand function parameters have already been obtained, the marginal cost of each firm can be estimated. Then as if it was observed it the marginal cost function, which is assumed to depends on the number of SSs hold within a region, s_{it}, can be estimated by OLS:

$$log(\hat{mc}_{it}) = \alpha_3 + \alpha_4 log(s_{it}) + \epsilon_{it}. \tag{18}$$

[15] The subscript r labeling a regional market is dropped.

[16] Estimating cost function parameters by imposing an assumption on an equilibrium behavior is common in the literature, e.g. Berry et al. (1995). Recently, Rosen (2007) propose an alternative approach where any equilibrium assumption is not imposed. By applying the concept of partial identification, he places bounds to estimate a marginal cost. Such approach is quite interesting but I do not pursue it here.

Market specific effects on the marginal cost are also included. An unobserved cost shock ϵ_{it} is assumed to be i.i.d and not considered as a state variable here for simplicity.

Before proceeding to estimation of policy function, a clear drawback in this estimation procedure should be noted. Fixed cost f_{ss} can not be identified because it is dropped out from the first order condition. Unfortunately we do not have the data about the minimum cost required to operate a SS annually. Therefore, as explained in the later section, my estimates of parameters of the scrap value distribution would include the amount of the future savings of fixed costs.

Divestment Policy Function The last empirical object in the first step is the equilibrium policy function governing divestment behaviors. The theoretical model suggests that the equilibrium policy function should be a function of the current state variable and a random scrap value. Further it is a cutoff strategy due to the indivisible nature of the facility, SS. The cutoff strategy means the policy function is weakly increasing in ϕ_i rather than strictly increasing.[17]

The weakly increasing policy function does not allow me to use straightforwardly the method of Bajari, Benkard and Levin (2007), in which a policy function strictly increasing in private shock is considered. Therefore I employ an alternative approach to estimate the policy function. This approach proceeds first to estimate the choice probability of all possible actions at each state from the data and, then, to calculate the equilibrium cutoff points by inverting the estimated distribution function at each state. These equilibrium cutoff points correspond to the equilibrium policy rule.

Let $G(d_i|\omega)$ be the probability that firm i takes action less than or equal to d_i. Following the theoretical model, this cumulative distribution function can be written

[17] In related work Olley and Pakes (1996) use a nonparametrics to get around the problem of computing value function needed to obtain a policy function. They describe a policy function as a higher order function of state variables without solving the complex dynamic programming problem to control for unobserved productivity shock.

as

$$
\begin{aligned}
G(d_i|\omega) &= \int_{-\infty}^{\bar{W}_{d_i}(\omega)} dF(\phi;\mu,k^2) \\
&= F(\bar{W}_{d_i}(\omega);\mu,k^2)
\end{aligned} \tag{19}
$$

where $\bar{W}_{d_i}(\omega) = \beta\big(W(d_i|\omega) - W(d_i+1|\omega)\big)$ represents the cutoff point in which firm i is indifferent between divesting d_i unit of its SSs and one more unit than d_i and μ and k are unknown parameter of the distribution of F. Inverting the above equation, the cutoff point can be expressed as a function of the probability $G(d_i|\omega)$:

$$
\bar{W}_{d_i}(\omega) = F^{-1}(G(d_i|\omega);\mu,k^2). \tag{20}
$$

This cutoff point can be interpreted as the equilibrium policy rule itself; when firm i knows its scrap value beyond this level, it does divest d_i unit of its SSs. If the cutoff points at each state are estimated and the distribution of private value is known, how firms will behave at each state can be predicted.

To estimate the equilibrium policy function, this approach needs only to estimate the probability $G(d_i|\omega)$ at each state and the knowledge of the distribution F. While optimal estimator for $G(d_i|\omega)$ would be a simple nonparametric description what the firm does at every state, the choice probability is estimated parametrically by a count data regression of Hauseman, Hall and Griliches (1984) and obtain the cumulative probability distribution function at each state $G(d_i|\omega;\gamma)$. This parametric approach is chosen over a non-parametric spell frequency estimator because of the sample size used in this study.With the estimated probabilities of all possible actions at each state, the cutoff points can be calculated, and a randomly drawn scrap value determines the divestment behavior based on the cutoff points.

In estimating the policy function, it is important to control for unobserved state variables. Due to the presence of the unobserved state variables, a different equilibrium can arise in different markets even if these two markets are observationally equal. When using the sample including several markets, controlling for the unobserved market specific effects is particularly essential for obtaining consistent estimates of the policy function. Therefore I include market specific effects controlling for the effect of these unobservables on the observed equilibrium behaviors with the assumption that the unobserved state variables are constant over time.

Value Functions The key point of the two step estimation procedure is to estimate the equilibrium value functions by using the estimated policy function. Since the equilibrium value functions can be exploited to estimate the dynamic structural parameters in the next step, they are the most important ingredients in the estimation. I estimate the value functions by averaging many simulated paths starting at observed states, which are generated by the estimated policy function. This technique is known as forward simulation which is initiated by Hotz, Miller, Smith and Sanders (1994), and extended to multiple agents' decision problems by Bajari, Benkard and Levin (2007).

Given a starting state, each simulation path is generated in the following steps:

1. Set a starting state $\omega_0 = \omega$. [18]

2. Draw scrap values $\phi_i(\phi_{-i})$ from the standard normal distribution and determine actions $d_i(d_{-i})$.

3. Calculate the per-period profit $u_i(\omega)$.

4. Update the firms' state variables and the demand level following the divestment decisions and the demand transition probability.

5. Repeat the step 1-4 for T periods.

[18] All the value functions at both the observed states and one period reachable states from those states are estimated. The maximum number of SSs scrapped at a period is restricted to four, which is the maximum of the observed divestment behaviors. Even if firms were allowed to divest its SSs more than four units, the estimated cumulative probability $G(d|\omega;\hat{\gamma})$ approaches to one until $d = 4$ in almost all states. So this restriction will be innocuous.

The equilibrium value functions are estimated by averaging 200 paths per each starting state constructed by the above manner. Each path has the length in 100 periods and discount factor β is set 0.925. Instead of (pseudo) random draws, draws from Halton sequence are used to reduce the computational burden while keeping the value function approximations precise. According to Train (2003), since they have superior coverage properties and smaller simulation errors, Halton draws are far more effective for a simulation estimator than (pseudo) random draws. The expected value function of firm i starting from ω can be approximated by

$$\frac{1}{H}\sum_{h=1}^{H}\left[\sum_{t=0}^{\infty}\beta^t\hat{\pi}_i^h(\omega_t,\hat{d}(\omega_t,\phi_t),\phi_{it};\theta)|\omega_0=\omega;\theta\right].$$

H is the number of draws form Halton sequence.[19]

5.2 Second Step Estimation

In the second step, by exploiting the equilibrium conditions, the dynamic structural parameters are recovered, which are the mean μ and variance k^2 of the scrap value distribution. But, as explained in the previous section, the estimated profit function doesn't include fixed cost f_{ss}. Therefore, the amount of future savings on fixed costs

[19] To reduce the computational burden the linearity assumption in payoff function is exploited. Recall the per-period cashflow is

$$\begin{aligned}\hat{\pi}_i(\omega_t;\theta) &= \hat{u}_{it}+\phi_{it}\hat{d}_{it}\\ &= \hat{u}_{it}+(\mu+k\nu_{it})*\hat{d}_{it}.\end{aligned}$$

$\hat{u}_{it}$ is the product market profit and $\hat{d}_{it}$ is the number of SSs scrapped, which depends on the choice probability estimates $G(d_i|\omega;\hat{\gamma})$. Notice the unknown parameters (μ,k) are enter linearly in the per-period cashflow. Therefore, the expected value function of firm i starting from ω can be rewritten by

$$\begin{aligned}\hat{V}_i(\omega;\theta) &= \frac{1}{H}\sum_{h=1}^{H}\left[\sum_{t=0}^{\infty}\beta^t\hat{u}_{it}^h(\omega_t)+\mu\sum_{t=0}^{\infty}\beta^t\hat{d}_{it}^h+k\sum_{t=0}^{\infty}\hat{d}_{it}^h\nu_{it}^h\right]\\ &= \xi_i(\omega,\hat{d})\cdot\theta \qquad (21)\end{aligned}$$

where $\xi(\omega,d)=(\frac{1}{H}\sum_{h=1}^{H}\sum_{t=0}^{\infty}\beta^t\hat{u}_i^h(\omega_t),\frac{1}{H}\sum_{h=1}^{H}\sum_{t=0}^{\infty}\beta^t\hat{d}_{it}^h,\frac{1}{H}\sum_{h=1}^{H}\sum_{t=0}^{\infty}\hat{d}_{it}^h\nu_{it}^h)$ and $\theta=(1,\mu,k)$. By this linearity, the computation of the value functions are done only at once.

by the reduction of a SS at the current period will be contained into estimates of the mean and variance of the scrap value distribution (μ, k^2). In estimating the structural parameters I have to recognize this point. The best thing I can do here is to obtain parameter estimates of $(\tilde{\mu}, \tilde{k}^2)$, not (μ, k^2). In the later section we will try to separate fixed cost from the estimates $(\hat{\tilde{\mu}}, \hat{\tilde{k}}^2)$ by utilizing an additional information.

Let $\theta = (\tilde{\mu}, \tilde{k}^2)$ a vector of the parameters of interest. Define the equilibrium condition at a state ω

$$P^{*D_\omega}(\hat{\gamma}|\omega) - \Psi\big(\hat{V}^{D_\omega}(\mathbf{P}^*(\hat{\gamma}), \hat{\alpha}, \theta|\omega); \theta\big) = 0. \tag{22}$$

$P^{*D_\omega}(\hat{\gamma}|\omega)$ is a vector of probabilities of possible actions at ω and $V^{D_\omega}(\mathbf{P}^*(\hat{\gamma}), \hat{\alpha}, \theta|\omega)$ is a vector of estimated value functions at states that are reachable in one period from the current state. D_ω indicates the choice set at state ω.[20] The estimated value functions depend on the first stage estimates, the choice probabilities $\mathbf{P}^*(\hat{\gamma})$ and the profit function parameters $\hat{\alpha}$, and the parameters of interest, θ.

The asymptotic least square estimator $\hat{\theta}(W)$ is a solution to the problem minimizing the metric of sample counterpart to the orthogonality condition:

$$\min_{\theta} \big[\mathbf{g}(\hat{\gamma}, \hat{\alpha}, \theta)\big]' \mathbf{W} \big[\mathbf{g}(\hat{\gamma}, \hat{\alpha}, \theta)\big] \tag{23}$$

where $\mathbf{g}(\hat{\gamma}, \hat{\alpha}, \theta) = \mathbf{P}^*(\hat{\gamma}) - \mathbf{\Psi}\big(\hat{\mathbf{V}}(\mathbf{P}^*(\hat{\gamma}), \hat{\alpha}, \theta); \theta\big)$. The weighting matrix W used here is $\big(\sum_\omega \sum_i D_{\omega_i}\big)$-square identity matrix. In general asymptotic least squares estimators depend on the choice of weighting matrix and this identity matrix is not the optimal weighting matrix. But Pesendorfer and Shmidt-Dengler (2008) shows in their Monte Carlo study that in a relatively small sample size the simple identity weighting matrix is preferred over the optimal one. All observed states across six markets are used to estimate the dynamic parameters, which are assumed to be the same value across these

[20]As previously noted, the maximum number of SSs scrapped is restricted to four.

markets.

The variance-covariance matrix of $\hat{\theta}$ is complicated since it depends on the variances of the first stage parameters estimates $\hat{\alpha}$ and $\hat{\gamma}$ (Newey and McFadden (1994)). Further the value functions V is approximated by simulation method, simulation error also affects the variance of structural parameter estimates $\hat{\theta}$ (McFadden (1989) and Pakes and Pollard (1989)). Accounting for these influences, the estimates of variance and covariance matrix $\mathbf{\Omega}$ is given by

$$\left(1+\frac{1}{H}\right)\left[\mathbf{G}_\theta\mathbf{W}\mathbf{G}_\theta\right]^{-1}\mathbf{G}_\theta\mathbf{W}\mathbf{V}\mathbf{W}\mathbf{G}_\theta\left[\mathbf{G}_\theta\mathbf{W}\mathbf{G}_\theta\right]^{-1} \tag{24}$$

where H is the number of simulation draws from Halton sequence and $\mathbf{G}_\theta = \nabla_\theta \mathbf{g}(\gamma,\alpha,\theta)$ and

$$\begin{aligned}\mathbf{V} = \quad & \{\mathbf{g}(\gamma,\alpha,\theta) + \nabla_\gamma \mathbf{g}(\gamma,\alpha,\theta)(\hat{\gamma}-\gamma) + \nabla_\alpha \mathbf{g}(\gamma,\alpha,\theta)(\hat{\alpha}-\alpha)\} \\ & \times\{\mathbf{g}(\gamma,\alpha,\theta) + \nabla_\gamma \mathbf{g}(\gamma,\alpha,\theta)(\hat{\gamma}-\gamma) + \nabla_\alpha \mathbf{g}(\gamma,\alpha,\theta)(\hat{\alpha}-\alpha)\}'. \end{aligned} \tag{25}$$

6 Estimation Results

I have described the model of dynamic oligopoly and the estimation procedure by the two-step approach which can circumvent the problems arising in the estimation of a dynamic decision model. This section presents the results of the estimation.

6.1 Results of the First Step Estimation

Demand Function Table 6 shows the results of demand function estimation. In estimating demand function, one period lagged values of price and quantity sold are served as the instrumental variables. To control for market specific effects on quantity, dummy variables for regional markets are also included. The estimated price coefficient α_1 has an expected sign and its value of 1.3 falls within a reasonable range. All of the region specific effects are significant and so demand conditions are different across six regions. The amount of nationwide construction investments is used as the demand shifter in all regional markets. The regional level of investments in construction could be used, but it almost perfectly correlates with regional quantity. Due to this the price elasticity could not be estimated reasonably. Therefore the demand shifter is considered to account for the nationwide trend of cement demand while the fixed effects are indicating the demand levels of individual markets.

Cost Function Parameter estimates of cost function are presented in Table 7. As expected, the more SSs it have within a region, a cement firm can reduce it's marginal cost of delivering product since it is likely to avoid a long haul carriage by its distribution management across own SSs. Adjusted R-square in the estimation is around 0.78 and indicates the fit of this specification is reasonably good.

Further to check how the model can predict the observed outcomes, Cournot equilibrium in each region at each year is solved by estimated demand and cost functions, and then the model predictions are compared with the observed quantities. The result is in Table 8. The model can predict the observed quantities quite well in upper quantiles although in lower quantiles the predictions are imprecise. I are optimistic about this result despite such prediction errors in the lower quantiles. This is because such poor predictions in lower quantities will have a very limited impact on the total quantities and the producers surplus (and of course on the consumers surplus) since the share of small firms is very tiny. The important thing is that the model can predict very well relatively larger firms' quantity-setting behaviors. This is essential for our research.

Policy Function To obtain the equilibrium policy rule, at first, the probabilities of observing all possible actions at each state are estimated by count data regression and the cumulative probabilities are calculated. Then, a cutoff point $\bar{W}_{d_i}(\omega)$ are calculated by inverting the (standard) normal distribution and evaluating the inverted distribution at the point of $G(d_i|\omega;\hat{\gamma})$ in the way proposed in the previous section.

Table 9 presents the result of poisson regression. I regress each firm action on the state variables, own number of SSs, competitors' number of SSs and exogenous demand shock. Also market fixed effects are considered to control for an unobserved state variable which affects the equilibrium behavior.

Table 10 summarizes the prediction precision of the estimated policy rule. The percentage of each action predicted by the estimated policy rule is compared with the observed actions. I draw 100 scrap values from the standard normal distribution per each firm at each period and calculate the frequencies of actions. For the sake of comparison, the same exercise is conducted by using extreme value distribution. Table 10 shows the normal distribution can predict divestment behaviors better than the extreme value distribution. The correlation coefficient also supports the normal distribution.

6.2 Result of the Second Step Estimation

In the second step we search for the values of parameters, $\tilde{\mu}$ and $\tilde{k}$, minimizing the distance between the observed divestment behaviors and the model predictions. Parameter estimates of the scrap value distribution are presented in Table 11. The estimates shows the distribution is very tight, but the variance is not estimated significantly. This result implies that cement firms are very sure about scrap values and savings on fixed cost of other competitors' SSs and they encounters small uncertainty about their rivals' capacity removal decisions. A convincing explanation on this result will be that land price be a very good proxy for a sell-off value and firms can estimate their values of removing a SS from such easily accessible information.

Fixed cost As mentioned earlier, the fixed cost of holding a SS, f_{ss}, can not be identified and therefore estimates of the scrap value distribution contains the sum of savings on fixed cost from the period of removing a SS on. I try to resolve this problem with the additional data on land price and two reasonable assumptions. First, it is assumed that only the mean of scrap distribution contains the value of reducing a SS and the variance is not affected. This implies that uncertainty among players comes from only a privately known scrap value as defined in the theoretical model. Second, the most of the scrap value is assumed to be land price. Thus estimate of the mean $\tilde{\mu}$ can be understood as the sum of the land price and the future streams of savings on fixed cost from the date of removing a SS on. With the assumptions and the data on the land price, the per-period fixed cost f_{ss} can be separated out from $\hat{\tilde{\mu}}$.

The median of land prices in six regions over the sample period is 100,000 yen per square meter and the average size of SSs is 10,000 square meters.[21] Therefore the implied sell-off value is ten billion yen. Then the average value of saving on fixed cost can be calculated by $(1-\beta) \times (\hat{\tilde{\mu}} - 10B)$. This value can be understood as the per-period fixed cost and it is about 30 million yen.

7 Simulation Exercise

In previous sections we have proposed a model of facility-reducing behaviors in dynamic environment and recovered its underlying parameters. Once structural parameters governing dynamics are recovered, an experimental exercise can be conducted by solving an MPNE under hypothetical market structures. The interest lies in evaluating the welfare impacts of horizontal mergers. To quantify the effect of horizontal mergers on consumers, producers and total welfare, this experimental exercise considers a counterfactual environment where any mergers do not take place and compares the market

[21] The figure is the median of land prices of industrial areas and they are collected from official announcement of land price by Ministry of Land, Infrastructure, Transport and Tourism. The average area of SS is calculated from annual securities reports of Taiheiyo cement and Sumitomo-Osaka cement.

outcomes with outcomes from a market with mergers.

Ideally the counterfactual market should have the same number of firms as the real world market had before mergers. But the computational burden for solving an MPNE can not allow me to conduct such complete experiment.[22] Therefore we consider a market with seven independent firms as a counterfactual environment and compare it with another where three of the seven firms are involved in mergers.

Even in a moderate market size, solving the theoretical model is computationally demanding. A very useful algorithm for computing equilibria of stochastic dynamic games is provided by Pakes and McGuire (1994) and it becomes a common tool for applied researchers in the field.[23] Although their algorithm could be applied, an alternative way exploiting the unique structure of the model considered here can alleviate the computational burden slightly. In this model the movements of the state variables are weakly unidirectional. The number of firms' SSs only goes down and the demand level also goes to a lower level, and once the states reach to a terminal state, this state lasts forever. Therefore the value functions in the terminal state can be easily calculated because they are just the sum of future cash flows at the states, and then the remaining states can be solved by a backward induction procedure.[24] This backward induction can save the computational time.

Once solving the model in both the experimental environments and obtaining the policy functions, I can make simulation paths in two starting configurations. The starting state in the counterfactual market without any mergers is based on the average size of the largest seven firms in the observed six markets at 1993, the year just before the merger wave. The state vector starts at $\omega = (11, 10, 9, 8, 7, 4, 4, z)$. Another market

[22] In 1993 (just before four big mergers) the average number of firms operating in a market is about nine. The state space will be too large to solve an equilibrium of the model.

[23] Pakes and McGuire (2001) propose a stochastic algorithm to break the 'curse of dimensionality' in solving equilibria of a recurrent class model. Although their algorithm can deal with the large number of firms, the model considered in this study does not belong to this class.

[24] This algorithm is completely opposite to that of Judd, Schmeddes and Yeltekin (2006). They consider a patent race where the state variables only go up to the higher states.

with four mergers starts at $\omega = (21, 15, 9, 8, z)$. This starting state is based on the fact that if all observed mergers had occurred in 1994 the average shares of merged firms in terms of SSs would have been 40%, 25% and 15% at that time.[25] The observed construction investment in 1994 is used as the starting demand level z for both markets. This experimental exercise approximately tells about what would have happened to the cement industry if any mergers had not taken place.

The results are summarized in Table 12. 100 sample paths having length of ten years for each market are generated and the sample average of these paths is reported. Consumer surplus is based on equation (5). Producer surplus is based on equation (4), but does not include fixed costs. Fixed cost indicates the sum of fixed cost incurred and Scrap value is the total sell-off values of SSs. Total welfare measures the sum of consumer surplus, producer surplus, fixed costs and scrap values. The last column in the table displays the following effects of mergers. The mergers decreases consumer surplus by 15.60 billion yen. On the other hand, it increases producer surplus by 24 billion yen. Furthermore, the market with mergers saves fixed cost by 0.8 billion yen by the reduction of SSs and receives scrap values of 9.5 billion yen more than the counterfactual market. The total welfare effect of mergers is 18.63 billion yen.[26]

The result reveals that the mergers increase the total welfare. The large part of the positive welfare effect stems from an increase in the producers surplus while as easily expected the consumers surplus is decreased by the mergers. As a firm gets bigger it can coordinate their supply among its SSs and reduce the transportation cost by avoiding long haul carriages. Therefore the merged firm can enjoy the cost efficiency gain substantially. This efficiency gain is large enough to overwhelm the loss of the consumers surplus. Further, the third and fourth elements in Table 12 shows the fact that firms in the merged market scraps SSs more than firms do in another

[25] A same firm was involved in merger twice.

[26] But, the magnitude is extremely small. The mergers can improve total welfare only by less than 2% points in this experment.

market. Eventually, firms receive more scrap values and pay less of fixed costs in the market with mergers and these two effects also contribute to the improvement of the producers welfare. Surprisingly, the total amount of these two values exceeds the welfare improvement measured by the difference between the consumers surplus and the producers surplus. As pointed out in Stigler (1968) and more formally in Berry and Pakes (1993), this result emphasizes the importance of taking into account the effects of outcomes arising from the dynamic decision process on the total welfare in evaluating mergers.

So why does the merging firms scrap more? Divesting facilities can be regarded as a public good that must be provided privately. The resulting high price caused by the reduction of a facility is beneficial for all market participants and firms thus have the incentive for free-riding on someone else's divestment. Merged firms can internalize this spill-over effect of divestment partially. Consider that a firm, A, merges one of competitors, B. Suppose that after the merger the merged firm scraps one of its SSs and raises the equilibrium price. In this case, the benefit of the high price enjoyed by firm B(A) is completely for firm A(B)'s own profit. The merged firm can partially internalize the business-stealing effect and, as a result, has the stronger incentive for divesting facility than a non-merged firm has.

The experiment shows that the merger induced facility removals can improve the total welfare. The main reason of this result is that an MPNE will fail to attain the socially desirable level of facilities in spirit of Mankiw and Whinston (1986). In an oligopolistic industry a facility is held partly or possibly mostly by the business-stealing motive and can contribute to the total welfare only partly. If the sum of saving on fixed cost and sell-off value exceeds its contribution to the welfare, removing a facility can be beneficial. However, such divestment is not likely to be provided voluntarily for the above reason, and the excess facilities remain. The internalization effect by mergers can dissolve this and, as a result, the merger-indeuced divestment can achieve a higher welfare level.[27]

An important point is that the welfare loss due to the excessive facilities is more likely to be severe in declining periods because the welfare is increasingly impaired as the socially desired level of capacity decreases. Therefore dissolving the situation 'excessive capacity' can be more beneficial in declining industries and can be a specific reason for justifying mergers in such industries. (However, not only are abundant facilities just removed the number of firms is also reduced by mergers. The presence of the anticompetitive effect explains the very little effect of mergers on the total welfare improvement in this experiment.)

8 Conclusion

In an oligopolistic industry the presence of business-stealing effect and fixed cost induces socially excessive facilities. A facility hold by the business-stealing motive is only partly a gain as a whole and if saving on fixed cost and sell-off value are relatively large, removing it will lead to the welfare improvement. Further, since the welfare loss by the excessive facilities is expected to increase as the socially desirable level of capital assets decreases, how to reduce such facilities is a pressing issue in declining industries. But such divestment is not provided voluntarily since once a firm removes its capital his business will be stolen by his rivals. Thus, regardless of demand decline, socially excessive facilities will not be dissolved.

In this research we focused on the role of merger as a device of promoting divestment and examined whether the merger-induced divestment could improve the total welfare. In analyzing mergers in an environment such that industry's capital level constantly changed and demand level shifted down over time, we used the Markov perfect equilibrium framework of Ericson and Pakes (1995) to describe dynamic divestment decision

[27]Notice that in general a merger raises an equilibrium price and a profit. So this has an opposite effect on the incentive for divestment. The simulation result indicates that the internalization effect overwhelms this profit effect and consequently the facility removals are promoted by the mergers.

process. My simulation exercise showed that merged firm had more of incentive to scrap its facilities and such divestments by mergers can lead to the improvement of the welfare. Particularly savings on fixed cost plus sell-off values were very large contributions to the welfare improvement. This result will pose a critical policy question to the current merger guideline in many countries.

Finally, I have to note some shortcomings of this research and future research agenda. While I focused on behaviors after mergers, more realistic analysis can be conducted by incorporating endogenous merger decision processes into the theoretical model, such as Gowrisankaran (1999). Developing an empirical model of endogenous mergers will be an exciting research topic and also be beneficial for both academic researchers and competition policy makers. Further, this paper analyzed only an unilateral effect of horizontal mergers. The reduction of the number of incumbents may increase the possibility of collusive conducts within a market. In almost all cases, collusion raises price and thus is harmful to consumers, and it lowers consumer surplus further. Therefore, the welfare implication will be affected by such collusive conduct and may be overturned. Modeling collusion in a dynamic world is also one of the open research questions in IO and it is also an attractive research topic. The last point is that I treated each regional market as an independent market and assumed away the relation between divestment decisions across markets. If the correlation between markets exists, the divestment decision problem (and merger decision itself) will be a more complicated one, not the simple description in this research. In static and very limited market structure, this independent assumption can be relaxed (Jia (2009)). However the interdependence across markets in a dynamic game will largely increase the state variables of each firm and cause a severe computational problem. Although it has some difficulties, any extensions in this direction will expand the scope of empirical analyses in the literature.

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Figure 1: Cement consumption and construction investment

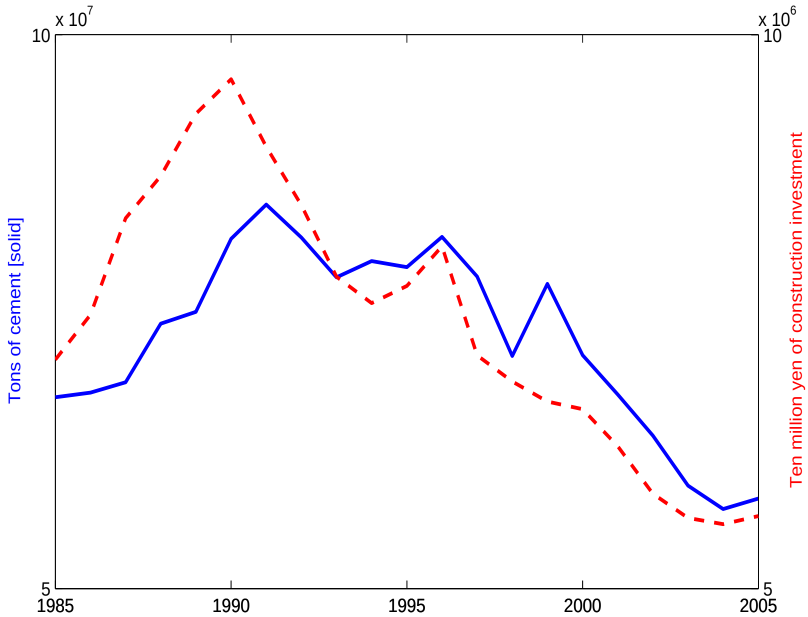

Table 1: Number of firms before and after mergers in each regional market.

Number of firms	Mean	Std. Dev.	Min	Max
Year 1993	9.12	1.66	7	12
Year 1998	5.95	1.21	4	8

Figure 2: Reduction of cement distribution facilities (service station)

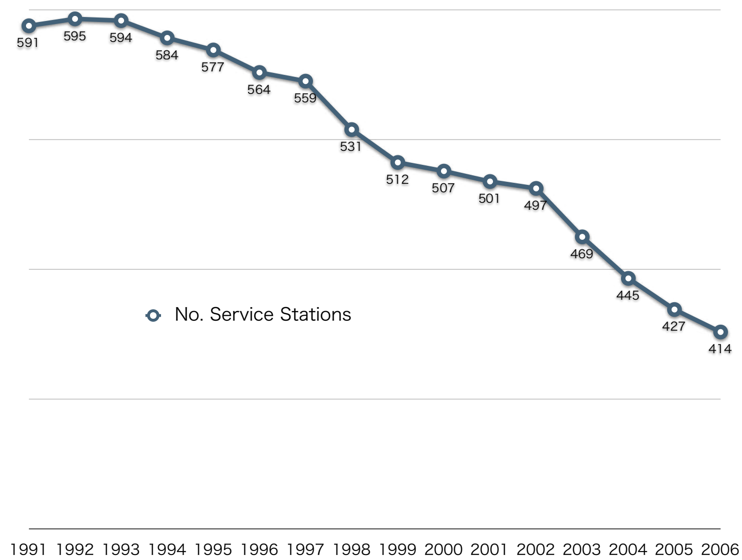

Table 2: Three firm concentration ratio. It is measured in terms of the number of service station in each regional market.

	Mean	Std. Dev.	Min	Max
Before Mergers				
1993	0.5642	0.1185	0.4410	0.7931
After Mergers				
1994	0.6312	0.1103	0.4950	0.7929
1998	0.8439	0.0918	0.7156	0.9539

Table 3: Merging firm share. It is measured in terms of the number of service stations in each regional market.

	Mean	Std. Dev.	Min	Max
1994	0.1912	0.0876	0.0303	0.3413
1998	0.2685	0.1169	0.0391	0.5184

Figure 3: The total number of service stations after mergers.

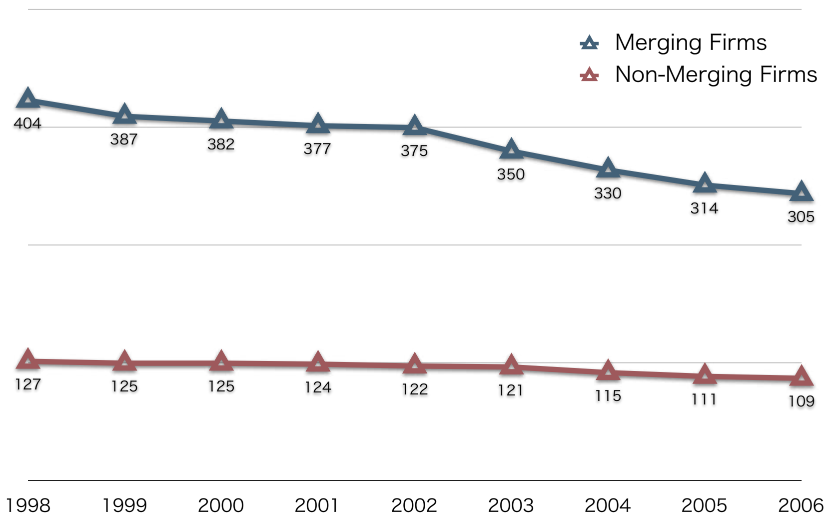

Figure 4: Price movement before and after mergers.

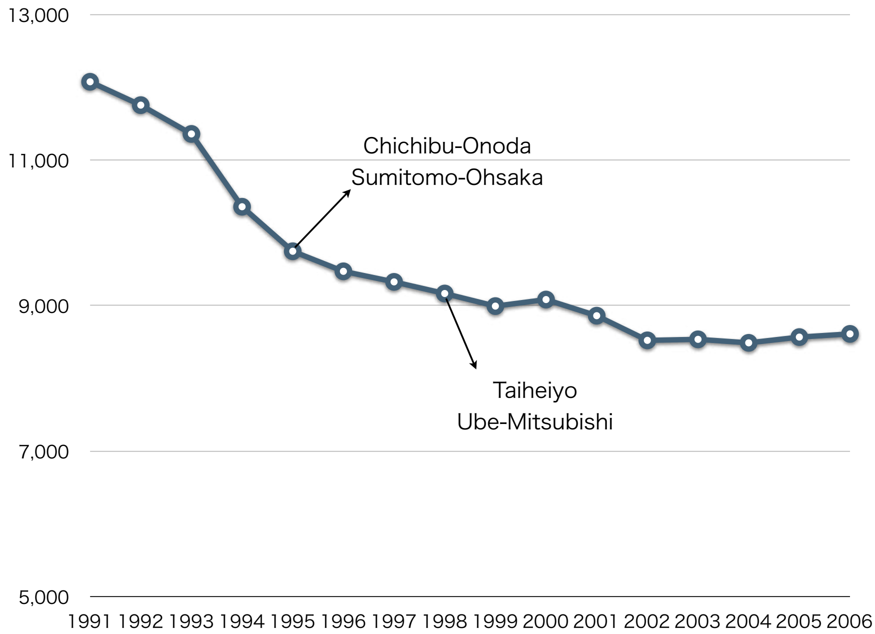

Table 4: Summary statistics. Price, Cement Consumption and Construction Inv. are the market level data. Unit of price and construction investment are yen and ten million yen respectively. Unit of cement consumption is ton. Supply Quantity, No.SS (service station) and Divestment are the firm level data. Unit of supply quantity is ton. Divestment is the number of service stations scrapped.

Variable	Obs	Mean	Std. Dev.	Min	Max
Price	54	9151.052	753.0521	8085.889	11632.79
Cement consumption	54	5927664	2707078	2416937	1.40E+07
Construction Inv.	54	5431458	2565688	1604066	1.19E+07
Suppy Quantity	261	1001235.628	845183.2219	82051	3447859
No.SS	261	8.4573	5.6237	1	26
Divestment	261	0.2935	0.7138	0	4

Table 5: Divestment frequency

Divestment	Freq.	Percent	Cum.
-4	2	0.77	0.77
-3	7	2.68	3.45
-2	11	4.21	7.66
-1	35	13.41	21.07
0	206	78.93	100
Total	261	100	

Table 6: Demand function parameter estimates. Price is the logarithm of the annual average price of an individual market. Construction Inv. is the logarithm of the sum of private and governmental construction investments. Hokkaido, Kinki, Shikoku, Tohoku and Tokai are market fixed effects (relative to Chugoku).

Variables	Coef.	Std. Err.
Price	-1.309	0.719
Construction Inv.	1.636	0.217
Hokkaido	-0.392	0.058
Kinki	0.595	0.068
Shikoku	-0.362	0.038
Tohoku	0.195	0.043
Tokai	0.430	0.089
Const.	-1.776	3.844
No.obs = 54		
Adj.R square = 0.9737		

Table 7: Cost function parameter estimates. No.SS is the number of firm's SSs in a region (in logarithm). Hokkaido, Kinki, Shikoku, Tohoku and Tokai are market fixed effects (relative to Chugoku).

Variables	Coef.	Std.err.
Cost.	9.2433	0.0152
No.SS	-0.1885	0.0148
Hokkaido	-0.0481	0.0142
Kinki	0.0569	0.0141
Shikoku	0.0232	0.0141
Tohoku	-0.1744	0.0149
Tokai	-0.1334	0.0056
No.obs = 261		
Adj.R square = 0.778		

Table 8: Quantity prediction. Predicted quantity is computed with estimated demand and cost function parameters.

Quantile	predicted quantity	observed quantity
10%	95083.9	168271
20%	408598.7	233807.9
30%	629789.7	460621.4
40%	755262.0	649979.8
50%	958510.2	805400
60%	1153626.2	1148229.4
70%	1377622.1	1483176
80%	1892844.1	1966102.6
90%	2372639.8	2392681.4
Mean	1071552.972	1034252.167

Table 9: Policy function estimates. NO.SS is the number of own SSs. Competitor j's SS is the number of competitor j' SSs, $j = \{1, 2, 3, 4\}$. The competitors are lined up in descending order based on the number of their SSs. Construction Inv. is the logarithm of the sum of private and governmental construction investments. Market specific effects are also included but not reported. The number of observations is 261.

Variables	Coef.	Std. Err.
No.SS	0.275	0.061
Competitor 1's No.SS	0.206	0.063
Competitor 2's No.SS	0.086	0.080
Competitor 3's No.SS	0.101	0.081
Competitor 4's No.SS	0.399	0.298
Construction Inv.	-10.423	3.018
Const.	175.627	51.114
Log likelihood = -106.2387		

Table 10: Policy function prediction. Compare the predicted frequencies of each action with the observed frequencies. Predicted values are calculated by drawing 100 scrap values from standard normal and extreme value distribution per each firm. Correlation coefficient indicates the correlation the mean of 100 actions of each firm and the observed actions.

Divestment	Normal	Extreme Value	Data
0	79.2	67.74	78.93
1	15.49	20.04	13.41
2	3.85	7.44	4.21
3	1.1	3.23	2.68
4	0.36	1.55	0.77
Correlation coef.	0.5294	0.5089	

Table 11: Structural parameter estimates. Estimates of mean and standard deviation of the scrap value distribution including the sum of future fixed cost savings. Unit is yen.

	Mean	Std. Err.
Mean of distribution $\tilde{\mu}$	1400275191	342745389.1
Std. Dev. of distribution $\tilde{k}$	55640912.47	143198533.5

Table 12: Welfare analysis. All values are the mean of 100 simulation paths of length 10 years. The starting state of the market without mergers is $\omega = (11, 10, 9, 8, 7, 4, 4, z)$ and that of the market with mergers is set $\omega = (21, 15, 9, 8, z)$ respectively. The starting demand level z is the amount of construction investment in year 1994 and common to both two markets. Units of all figures are billion yen.

	w/ Mergers	w/o Mergers	Difference
Consumers surplus	875.3185	890.9166	-15.5981
Producers surplus	78.786	54.78553	24.00046
Fixed cost	-8.4218	-9.219	0.7972
Scrap value	11.56814	2.140756	9.427386
Total welfare	957.2508	938.6239	18.62693