Assessing the Consequences of a Horizontal Merger and its Remedies in a Dynamic Environment [*]

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Abstract

This paper estimates a dynamic oligopoly model to assess the economic consequences of a horizontal merger that took place in 1970 to create the second largest global producer of steel. The paper solves a Markov perfect Nash equilibrium for the model and simulates the welfare effects of the horizontal merger. Estimates reveal that the merger enhanced the production efficiency of the merging party by a magnitude of 4.1 %, while the exercise of market power was restrained primarily by the presence of fringe competitors. The merger altered the nature of strategic interaction in investment behavior among firms. Our simulation result also indicates that structural remedies endorsed by the competition authority failed to promote competition.

Keywords: Horizontal merger; Dynamic oligopoly; Strategic interaction; Markov perfect equilibrium; Merger remedies

JEL: L13; L41; L61

1   Introduction

The economic approach to the evaluation of horizontal mergers stresses the trade-off between market power and efficiency gain. Mergers, which reduce the number of competitors, raise the possibility of strengthening market power and thus aggravating any deadweight loss. Conversely, mergers integrate productive facilities and introduce new production processes, leading to possible gains

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in efficiency. While the extant merger literature has devoted considerable attention to measuring the anticompetitive effect of horizontal mergers, remarkably little research has been conducted to examine their efficiency effect. Given the substantial increase in the number of mergers and acquisitions over recent years, evidence on the efficiency effects of horizontal mergers can provide important guidance for antitrust authorities, who decide whether a particular merger should be allowed, prohibited, or cleared subject to certain remedies. Since the efficiency effects of horizontal mergers are not always immediately apparent, empirical research that measures such effects requires a dynamic model that accounts for firms' intertemporal decision making.

This paper quantitatively assesses the welfare trade-off associated with a horizontal merger in an attempt to redress the lack of evidence of efficiency gain. For this purpose, the paper uses a unique case of a horizontal merger that occurred in the Japanese steel industry. In 1970, Japan celebrated the birth of Nippon Steel, the world's second largest steelmaker. The new Japanese company came into being through the merger of Yawata and Fuji, the two largest Japanese steel producers at the time. The merger was approved by the Japan Fair Trade Commission (J-FTC) under the condition that the merged parties would transfer a fraction of their productive capacities to their competitors.

A notable aspect of the Japanese steel industry in the postwar period was its active investment in new plants and equipment. Indeed, during the study period, the steel industry accounted for more than 15% of the manufacturing sector's capital investment expenditure. Buoyed by booming demand in the 1960s, the steel industry vigorously introduced a number of new steel-making furnaces that utilized advanced cost-reducing technologies. As production capacity expanded, the annual output of crude steel — which began at five hundred thousand tons in 1950 — doubled every five years; this elevated Japan to the status of the world's largest steel exporter by 1969. This paper quantifies the extent to which investment on capital affected steel production and explicitly accounts for the dynamics resulting from firms' capital investment behavior.

Although there does not appear to exist any opportunity to conduct controlled experiments on the 1970 merger, we can still perform counterfactual exercises by following two steps. The first is to use observed data along with an economic model to recover the estimated parameters of the underlying economic primitives that were invariant in the horizontal merger. We then construct a theoretical model of the steel industry, where oligopolists make optimal decisions regarding production and investment on the basis of their competitors' strategies. The second step involves using the model to simulate changes in equilibrium outcomes on the basis of the counterfactual situation in which Yawata and Fuji do not engage in the merger. We also consider another counterfactual situation in which the merger took place in the absence of the merger remedies. For the simulation approach to be successful, the model used for the exercise must closely approximate the economic

environment under study. We follow the research of Ericson and Pakes (1995) and use the method of Bajari, Benkard, and Levin (2007) to compute a Markov-perfect equilibrium of the dynamic game in order to account for the firms' capital investment processes.

The estimation results show that the merger under study substantially enhanced production efficiency and far exceeded the welfare loss associated with an increase in market power. The paper finds that the merger reduced the marginal cost of production for the merging party by a magnitude of 4.1 %. Conversely, despite the fact that the combined market share of Yawata and Fuji was nearly fifty percent of the market under our study, the merger raised steel prices by a mere one-fifth of one percent. The post-merger price would not have much increased because steel demand is estimated to be price elastic. Indeed, the post-merger price may well have been constrained by the presence of electric arc furnaces, which was an alternative source of steel supplied by emerging minimills. As a result, the merger may have improved the social surplus (i.e., the sum of the consumer and producer surpluses) by approximately 45 %, as compared with a situation in which no merger had taken place.

It is interesting to note that the merger enhanced production efficiency not only for the merging party, but also for the non-merging parties. Our estimates of the equilibrium policy function imply that after the merger, firm investment activities turned into strategic substitutes, which is in stark contrast to the pre-merger period in which the activities were complemented strategically. This change in strategic relationships in terms of firm investment activities corroborates with the developments reported in trade journals. Hence, while Nippon Steel exercised restraint with respect to capital investment, the non-merging companies increased their investment amounts in response to the merger, thereby improving their productive efficiency.

The paper also assesses the effectiveness of the merger remedies accepted in the negotiation process between the J-FTC and the companies involved in the merger. Competition authorities are entitled to accept remedies from merging parties on the condition that the remedies are proportionate to anticompetitive concerns. Without such remedies, merger decisions would be binary (either prohibited or cleared). Remedies are therefore supposed to constitute an additional tool for competition authorities to resolve the competition problems generated by a merger while preserving the prospective efficiencies. Accordingly, the 1970 merger was approved under the condition that the merging party would transfer a total of 1.8 % of its capital equipment to two smaller firms, namely, Nihon Kokan and Kobe. Our ex-post simulation results show that, although this condition helped the two firms remain viable competitors in the market, the divestiture failed to achieve the full efficiencies that should have been realized from the merger. That is, our estimate indicates that the merging party would have made better use of the transferred capital than did either Nihon Kokan or Kobe. As a result, the proposed divestiture exacerbated social welfare by

JPY 21 billion (USD 700 million) annually during the study period. While this welfare calculation uses ex-post information, it is also instructive to consider the proposed merger remedies from the ex-ante perspective by use of the pre-merger information available up to 1969. A casual examination of the estimates of both the investment policy and marginal cost functions shows that the J-FTC's decision to accept the proposed merger remedies might not have been reasonable. On the basis of the information publicly available at the time of the J-FTC's merger decision, the paper finds that the allocation of capital from the merged party to the two smaller companies would have made little economic sense at the time, since the proposed divestiture would have been expected to neither increase capital investment nor enhance productive efficiency at the industry level.

This paper's contributions to the empirical literature on horizontal mergers are twofold. First, this study is the first to assess the productive efficiency accrued by a particular merger case by explicitly taking into account the dynamic nature of investment choice. Over the past decade, a large body of literature has devoted considerable attention to predicting the price effect of hypothetical or actual horizontal mergers in various industries (e.g., Dube, 2004; Peters, 2006). However, as noted by Whinston (2006; 127), remarkably few research works have examined the effects of horizontal mergers on productive efficiency.[1] One work that explicitly quantifies such effects is Pesendorfer's (2003) research on the U.S. paper and pulp market. He employs a static model to examine the effects of capacity investment on a mergers outcome, and the model assumes that the mergers have no effect on the firm's investment behavior. This paper extends his model to a dynamic context and allows for strategic interaction in firm investment behavior. The paper finds that the nature of the firm's investment behavior was considerably altered at the time of the merger, and that neglecting this feature would overstate the efficiency effect of the merger in our application of the Japanese steel industry. [2]

Second, this paper contributes to a small but important body of literature involving empirical assessments of the effectiveness of merger remedies. To our knowledge, only one study on this topic, conducted by Davies and Lyons (2008), empirically uses a static framework to assess the design of merger remedies employed in the European Union (EU) paper and pharmaceutical industries. Compared with their work, this paper focuses solely on divestiture and allows a firm's dynamic investment decision-making processes to quantify the effectiveness of the merger remedies. While divestiture commitments tend to be preferred by competition authorities (FTC, 1999), this paper

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[1] Many merger studies using dynamic models are based on numerical calibration, and not on an empirical method. Previous work on numerical analyses includes Compte, Jenny, and Rey (2002) and Chen (2008).

[2] In a section of their analysis, Hashmi and Biesebroeck (2007) also examine the effect of mergers in a global auto market by using a dynamic model. However, their research interest lies in the changes in the number of patents owned by firms; this differs considerably from our focus on the steel industry, where several patents were filed during the study period.

finds that the proposed remedies under study did not appeared to improve welfare from either ex-post or ex-ante perspective.

The rest of this paper is organized as follows. Section 2 provides an overview of the Japanese steel industry in the postwar period, particularly the merger between Yawata and Fuji in 1970. This section also evaluates the merger from a static perspective, following the approach proposed by Farrell and Shapiro (1990). The analysis finds that an examination of the traditional criteria with the Herfindahl-Hirschman index (HHI) would likely result in a recommendation that the merger be challenged. On the other hand, the static equilibrium analysis indicates that the merger would improve social welfare if it was profitable for the merging firms. Section 3 presents a dynamic model that explicitly accounts for the dynamics arising from investment behavior, which was one of the most important features of the Japanese steel industry in the 1960s and 1970s. Section 4 discusses the estimation results. The results lead to three important findings; (1) steel demand was elastic with respect to price; (2) the marginal cost of production exhibited economies of scale in terms of both capacity size and the cost synergies associated with the merger; and (3) the merger changed the nature of strategic interaction in investment behavior among firms from one of strategic complement to one of strategic substitute. Using these results, Section 5 performs policy experiments to evaluate the welfare consequences of the horizontal steel merger and assess the effectiveness of divestiture as a merger remedy. Section 6 concludes and is followed by Data Appendix.

2   Historical Background and Preliminary Analysis

This section begins with a historical overview of the Japanese steel market, with particular emphasis on the study period 1960–1979. Section 2.1 illustrates that each firm's active investment was an important characteristic of the Japanese steel industry. The features of the market described in this section lead us to develop a dynamic structural model, which is discussed in Section 3. Before introducing such dynamic decision making, Section 2.2 uses the static analytical framework of Farrell and Shapiro (1990) to assess the welfare impact of the merger that took place between Yawata and Fuji in 1970. This static analysis is inadequate for the study of the steel merger, because it neglects the dynamic features of the firms' investment decision making; however, it provides a useful starting point from which to consider the effect of the 1970 merger. The static analysis in this section concludes that the steel merger improves social welfare so long as the merger is privately profitable.

2.1 Overview of the Industry

Yawata and Fuji were originally under the same ownership: this was dissolved in 1950 by the occupation forces, who were attempting to create a competitive environment for the Japanese steel industry. At the same time, the occupation forces established the J-FTC along with antitrust monopoly law. However, despite their efforts, only a handful of dominant major firms operated during the 1960s and 1970s. Indeed, over 80 % of the Japanese steel production was accounted for by integrated steel manufacturers. These manufacturers transformed raw materials (iron ore and coking coal) into pig iron in a blast furnace. Pig iron was then transformed in a refining furnace into crude steel, the homogeneous product on which we focus in this study.[3] The following seven integrated companies enjoyed the largest shares in the market: Nippon Steel, Yawata, Fuji, Nihon Kokan, Kawasaki, Sumitomo, and Kobe (in order of average market share). Note that Nippon Steel was created in 1970 by the merger between Yawata and Fuji. Since then, Nippon Steel has remained the second largest steel producer in the world — after U.S. Steel at the time of the merger and now after Arcelor Mittal. This paper focuses on the abovementioned seven Japanese integrated companies and characterizes the structure of the market. In the 1960s and 1970s, no entries and exits took place, except for those associated with the Yawata-Fuji merger. Therefore, during the study period, the Japanese steel market was of little relevance to the merger waves observed in other markets, including the U.S. paper and pulp industry studied by Pensendorfer (2003).

Beginning in the 1960s, integrated steel makers faced increasing competitive pressure from a new type of steel producer, namely minimills. In contrast to the integrated steel makers, minimills own no blast furnace but instead electric arc furnaces to use steel scrap and electricity as major inputs to produce crude steel. In the 1960s, minimills appeared to catch up with integrated steel makers in terms of production capacity size and crude steel quality, as electric arc furnaces began producing on an increasingly larger scale with supplies of high voltage electricity. Thus, the emergence of the alternative source of steel supplied by minimills should have increased the elasticity of steel demand faced by the integrated steel manufacturers.

Table 1 presents important statistics, classified according to the pre- and post-merger periods. The average price of crude steel increased by approximately 50 %. This price increase may not have been entirely due to the merger; recall that major oil crises occurred in 1973 and 1979. In Sections 4 and 5, we identify the extent to which the merger accounted for the price hike shown in the table.

In the 1960s and 1970s, the Japanese steel industry was characterized by firms' active investments in new plants and equipment. This feature is demonstrated by the index of the capital-labor

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[3]While we could alternatively focus on processed crude steel — namely, ordinary steel including bars, rails, and wires — firm output data are not available at this category level.

ratio, which is defined as the ratio of the value of tangible fixed assets to the number of employees. The index indicates that the capital intensity of the steel industry was three times higher than the average of the manufacturing sector and twice that of the chemical industry. In fact, Figure 1 shows that the production capacities of both blast and refining furnaces expanded at the rate of approximately 20 % during the study period. Note that the new production facilities utilized the latest technology, which further pushed firms' production frontiers and thus reduced the cost of steel making. Therefore, the active investment observed in the steel industry reflects the firms' incentives for efficient steel production in a market where only a handful of firms dominated. It is also worth noting that non-merging firms invested more in the post-merger period than in the pre-merger period: Table 1 shows that the average investment share of a non-merging firm became larger in the 1970s (13.70→17.37), whereas that of a merging party became smaller (45.21→30.52). In Section 3, we introduce the dynamic decision-making model to associate this finding with strategic interaction in investment behavior.

The rapid production growth indicated in Table 1 was accompanied by export expansion, and Japan's share of the world export market grew from less than 5% in 1955 to 9% in 1965. Most of Japan's steel had been shipped to Asian countries until the early 1960s, when an increasing proportion began to be exported to North America. Nevertheless, the steel export market was fairly competitive from 1955 to 1980, and there is little evidence that Japanese steelmakers had market power during that period. The Japan Iron and Steel Exporters' Association (1974) observed that the Japanese Freight on Board (FOB) steel price was not significantly different from the price in Antwerp, Belgium, which was known as the center of the world steel trade at that time. It is thus reasonable to assume that the exported steel was competitively supplied in the world market.[4]

Japan had an import tariff of 15% on steel until 1967 when it agreed to reduce the rate by half at the Kennedy Round of General Agreement of Tariffs and Trades (GATT). However, while the import tariff protected domestic steel makers from direct competition with foreign steel makers, it may have had little to do with the increase in Japanese steel production shown in Table 1, because Japan also exported steel during that period. Indeed, the share of steel imports accounted, on average, for a mere 0.2 % even after the tariff was reduced. We therefore assume that steel imports were not substituted by steel produced by Japanese companies and did not affect the domestic Japanese market.

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[4]This assumption is also consistent with the evidence presented in Ohashi (2005), which indicates that the export subsidy on Japanese steel was not based on profit shifting.

2.2 Static Analysis of the Merger

In evaluating a proposed merger, antitrust officials in the U.S. generally apply the rules summarized in the Department of Justice's Merger Guidelines (1992). Traditional merger analysis under the guidelines involves estimating the effect of a proposed merger on market concentration. Roughly speaking, the guidelines permit mergers that will result in either a low initial level of concentration in the industry or small predicted changes in concentration. In the guidelines, concentration is measured according to the HHI, which is defined as the sum of the squares of the firms' market shares. In retrospect, the initial level of and change in HHI due to the merger between Yawata and Fuji exceeded 1800 and 100, respectively, as shown in Table 2. Thus, unless further analysis indicates that entry would be easy or that important efficiencies would be created, the Merger Guidelines would most likely recommend that the merger be challenged.

Careful assessment of horizontal mergers requires in-depth analysis of how they will affect equilibrium output and welfare; however, this analysis was lacking in the abovementioned traditional approach using the concentration index. Farrell and Shapiro (1990) provide such an analysis in the context of Cournot competition in a homogeneous product market. One principle issue investigated by Farrell and Shapiro (1990) involved the identification of a sufficient condition for a merger to increase aggregate surplus provided that the proposed merger is profitable for the merging parties.[5] Suppose that firms in set I contemplate merging. Let q_i denote firm i's output and Q, the industry output. Under the presumption that the proposed merger is profitable for the merging firms, a sufficient condition for a merger to increase aggregate surplus is given as (in Whinston, 2006)

$$M_I < - \sum_{i \notin I} M_i \left(\frac{dq_i}{dQ} \right), \tag{1}$$

where M_i is firm i's premerger market share, M_I is the collective market share of the firms in set I, and $\frac{dq_i}{dQ}$ is the differential change in non-merging firm i's output when the industry output changes marginally. Eq. (1) establishes that the merger is welfare enhancing without the need to quantify the efficiencies created by the merger. That is, the condition is purely a function of premerger market shares and the non-merging firms' reactions to the merging firms' output reductions. According to Eq. (1), the proposed merger improves the aggregate welfare when the non-merging firms are large and increase their outputs upon the merger. Indeed, this is the case for the Yawata-Fuji merger: using the observed outcomes following the actual merger, which are shown in Table 1, we find that Eq. (1) holds, as $M_I = 45$, and the RHS is equal to 120.

Although Farrell and Shapiro (1990) provide a useful preliminary assessment of the particular merger, the approach relies on a static framework that does not fit well with the industry under

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[5]Another principle issue examined in Farrell and Shapiro (1990) involved the identification of the condition in which the proposed merger reduces the price.

study. One of the notable aspects of the steel industry in the postwar era was that the world steel market featured active investment on new plants and equipment. Further, the investment was propelled not only by surges of steel demand, especially in Europe and Northeast Asia, but also by advances in new technology, including the introduction of the basic oxygen furnace and large-scale blast furnaces. Indeed, the steel industry accounted for more than 15% of the capital investment expenditure in the Japanese manufacturing sector. Since investment is a main strategic choice variable in the steel industry, careful analysis of the steel merger between Yawata and Fuji requires a more complete model that accounts for a dynamic environment in which firms make intertemporal decisions on investment, such as the one we present in the next section.

3 A Dynamic Model of the Japanese Steel Industry

This section describes a model used to explain the Japanese steel market in the period from 1960 to 1979. We begin the section by providing an overview of the estimation model. In Section 3.1, we present the timing of the game used in the paper's analysis and introduce state variables and their transition equations. We then discuss the details of the model in the remaining section.

3.1 Overview of the Model

Our empirical goal is to evaluate the welfare effects of the 1970 merger between Yawata and Fuji by explicitly accounting for the dynamics resulting from investment behavior. The merger may have lessened competition in the steel market and simultaneously yielded efficiency gains in production. To assess this tradeoff, which was originally identified by Williamson (1968), it is necessary to construct a theoretical model that captures the salient features of the Japanese steel industry in the postwar era.

As described in Section 2, the Japanese steel market is characterized by active investment in capital; moreover, only a handful of dominant major firms operated in the market under minimal international competitive pressure. Capital investment improves production efficiency in future periods, whereas an oligopolistic market structure generates concerns for strategic behavior. Since these market features contain important implications for our assessment of the 1970 merger, we build a dynamic model of firm behavior that allows for strategic interactions between firms. We extend the model of dynamic competition proposed by Bajari, Benkard, and Levin (2007; hereafter BBL) to incorporate firms' intertemporal decision making about capital accumulation. The model used here represents a special BBL case in that we do not consider the issue of firms' entries and exits; no such events were observed in the data except for the 1970 merger under question.

There are N_t firms at time t, denoted by $i = 1, ..., N_t$. In our application, N_t takes the value 6

prior to 1970 and the value 5 after the merger. Our data set, which comprises annual data, covers the period from 1960 to 1979, indexed by t. The industry state at each period t is summarized by a vector of the commonly observed variables, s_t. This state vector includes the amount of public fixed capital formation (in 1960 prices), z_t, and a vector of capital stock k_t whose i-th component is firm i's capital stock $k_{i,t}$.[6] The variable z_t is used as a demand shifter, as discussed in Section 3.2.

At the beginning of period t, and given the state s_t, each firm makes its decision on the amount of investment, denoted by $I_{i,t}$. In the model, investment serves to enhance the efficiency of steel production through capital accumulation. No divestment was observed in the data primarily because of the high economic growth that occurred during the study period; thus, we do not consider the possibility of divestment in the paper. Each firm subsequently receives its private productivity shock $\eta_{i,t}$ and the industry-wide demand shock ξ_t and engages in competition in the crude steel market. The crude steel product is considered to be homogeneous, and firms simultaneously choose their quantities for each period t. Let $q_{i,t}$ denote firm i's quantity of crude steel chosen in period t, and Q_t denote the industry output, which is defined as the sum of $q_{i,t}$ over i. We assume that the shocks $\eta_{i,t}$ and ξ_t are drawn independently from each other across the periods. These shocks are considered to influence the current payoff and output quantities but have no effect on the future sequences of either shocks or outputs. Therefore, the equilibrium quantities are obtained using a static decision-making problem. We assumed that $\eta_{i,t}$ and ξ_t are independent over time; this is because the number of state variables would increase if otherwise, since firms would then presumably consider other firms' private states on the basis of their past actions.

Finally, we assume that an adjustment in capacity takes one year to implement. This assumption approximates the case of the steel industry, which experienced a time delay in the installation of production facilities, such as furnaces. More precisely, the transition of the capital stock is described as $k_{i,t+1} = (1 - \delta) k_{i,t} + I_{i,t}$, where the capital depreciation rate is common across firms and denoted by the exogenous parameter of $\delta \in [0, 1]$. Following the method of Ogawa and Kitasaka (1998), who calculate the capital depreciation rates of various manufacturing sectors, we set δ at 0.0805. Another state variable, z_t, is assumed to follow the path observed in the data. We denote $p(s_{t+1}|I_t, s_t)$ as the probability density that s_{t+1} is reached when the current state and action are given respectively by I_t and s_t, where I_t is the investment vector whose i-th component is $I_{i,t}$.

As discussed in Section 2, since no firms entered or exited the market during the study period, our model assumes that the number of active firms is exogenously given by N_t. Note that the timing of the game described above implies that each firm makes its production and investment

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[6]The gross national expenditure highly correlates with the transportation production index, the shipbuilding production index and the gross domestic capital formation in both the public and private sectors.

decisions without knowing the decisions of their competing firms.[7] In Section 3.2, we describe the model of output choice and define the firms' per-period payoffs.

3.2 Output Choice

We begin with the model of steel production technology. Availability of firm-level factor input data is limited; therefore, we build a cost function that describes the steel making process. We assume that an increase in the firm's capital reduces the marginal cost of production. This is a reasonable assumption because the firm's capital investments mostly take the form of augmenting new steel making furnaces, which utilize the latest cost-reducing technologies. Thus, it is likely that an increase in $k_{i,t}$ will improve productive efficiency. Since the firm's investment is capitalized at the end of the period, we model firm i's marginal cost at time t, $mc_{i,t}$, as the following form of the constant returns to scale with an additive error term $\eta_{i,t}$:

$$mc_{i,t} = f_t\left(k_{i,t}; \Theta^c\right) + \eta_{i,t}, \tag{2}$$

where Θ^c is the set of cost parameters to be estimated. Since we have no prior knowledge regarding the functional relationship between $mc_{i,t}$ and $k_{i,t}$, we use a polynomial-series estimator of $f_t\left(\cdot\right)$, as detailed in Section 4. The sign in the derivatives of $f_t\left(\cdot\right)$ with respect to $k_{i,t}$ is an empirical question of interest. To anticipate the result reported in the next section, we find the first derivative to be significantly negative: this is consistent with the hypothesis that an increase in the firm's capital reduces the marginal cost of steel production. Eq.(2) assumes no spillovers in that the benefits of making investments are fully appropriated within the firm. The characteristics of steel production mentioned above suggest that firm i's cost-reducing technology is not transferable to other firms because the technology is physically utilized in furnaces owned by the firm itself.

Other than the capital stock, important influences on the marginal cost include labor skills, research and development (R&D) activities, and utilization. Since no data that accurately reflect these influences are available, such supply shocks are captured by the term, $\eta_{i,t}$.[8] We allow this term to have firm- and time-specific components, denoted by ν_i and ϖ_t, respectively, in the estimation. Thus, $\eta_{i,t} \equiv \varphi_{i,t} + u_{i,t}$, where $\varphi_{i,t} \equiv \nu_i + \varpi_t$. The error term $u_{i,t}$ is the error drawn independently over i and t from the normal distribution $N\left(0, \sigma_u^2\right)$, where the variance parameter σ_u is to be estimated. In the estimation section, we relax the distributional assumption on $u_{i,t}$ to examine the

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[7]In the preliminary analysis, we modified the timing of the game and estimated the model under the assumption that the investment decision is made after firms observe $\eta_{i,t}$ and ξ_t. The results are available upon request. The main results have no significant effect on those reported in this paper.

[8]Hashmi and Biesebroeck (2007) uses data on patents to represent R&D activities. Japanese steel firms, however, filed few patents associated with their production technologies. Thus, it is difficult for us to quantify R&D activities by use of the method employed in Hashmi and Biesebroeck (2007).

robustness of the cost estimates. The fixed-effect treatment deals with any industry-wide supply shock as well as with the efficiency differences among firms that do not change over time.

Since it is difficult to find accurate cost data to directly analyze Eq.(2), we estimate the price-cost margins by building a competition model and thereby obtain the cost parameters. In particular, we construct a steel maker's profit maximization problem and solve the first-order condition. We establish the following supply-side model. Suppose that firm i competes and chooses its output at time t in the domestic market for crude steel. In each period t, firms face the domestic demand function $p_t\left(Q_t; z_t, \xi_t, \Theta^d\right)$, in which Θ^d is a set of demand parameters to be estimated. The other variables have been defined in the previous subsection. In this paper, we treat the amount of export as exogenously given because exported steel is reasonably assumed to be competitively supplied in the world market, as discussed in Section 2. We assume that z_t is observed by the econometrician, while ξ_t is unobserved. Nevertheless, since both the demand shifters are observed by firms, we correct for this potential endogeneity in Section 4. Moreover, the demand error, ξ_t, is assumed to be drawn independently across periods from the normal distribution $N\left(0, \sigma_\xi^2\right)$ while the variance parameter σ_ξ is to be estimated.

In each period, after the choice of investment, firm i observes the shocks ξ_t and $\eta_{i,t}$, and simultaneously chooses the output quantity $q_{i,t}$ to maximize the following per-period payoff:

$$\left(p_t\left(Q_t; z_t, \xi_t, \Theta^d\right) - mc_{i,t}\left(k_{i,t}, \eta_{i,t}; \Theta^c\right)\right) \cdot q_{i,t}. \tag{3}$$

Under the assumption made in Section 3.1, steel output and price are determined in the static equilibrium conditional on the current state. Hence, the maximized per-period payoff for firm i is a function of the current state vector and denoted by $\pi_{i,t}\left(s_t, \xi_t, \eta_{i,t}; \Theta\right)$, where $\Theta \equiv \left(\Theta^c, \Theta^d\right)$. The first-order condition derived from firm i's static profit maximization under Cournot competition takes the familiar form of the Lerner index, namely,

$$\frac{p_t - mc_{i,t}}{p_t} = \frac{1}{|\varepsilon_t|} \cdot \frac{q_{i,t}}{Q_t}, \tag{4}$$

where ε_t is the elasticity of demand with respect to price. We do not consider the possibility of capacity constraint in Eq.(4) because it is known to be difficult to define the maximum available production capacity in this industry. Note that the unit of measurement differs between $q_{i,t}$ and $k_{i,t}$; the former is in terms of physical tonnage, while the latter is in terms of monetary value (at 1960 prices). Since a small-sized furnace with advanced technology was often more expensive than a conventional large-scale furnace, it is nearly impossible to determine the link between the two variables in order to infer the utilization rate in this industry.

Using the demand estimates obtained in Section 4 and the data, we can derive $mc_{i,t}$ from the first-order condition in Eq. (4). In the next subsection, we construct the discounted future payoffs

and introduce a set of parameters associated with firm investment decisions.

3.3 Investment Choice

In this subsection, we describe the model of investment choice, or the decision that is made prior to the output choice. At the beginning of period t, and given the state s_t, each firm makes its decision on the investment amount prior to the realization of ξ_t and $\eta_{i,t}$. The investment decision is inherently dynamic because according to Eq.(2), a firm receives benefit from the investment in the future periods. In the investment choice, firm i is assumed to maximize the following expected future profit, evaluated prior to the realization of ξ_t and $\eta_{i,t}$:

$$E\left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[\pi_{i,\tau}\left(s_t, \xi_\tau, \eta_{i,\tau}; \Theta\right) - \phi\left(I_{i,\tau}; \theta\right)\right] | s_t\right],\tag{5}$$

where the expectation is taken over other firms' investment choices in the current and future periods as well as over the current and future values of all the state variables and private shocks. The maximized per-period payoff, $\pi_{i,\tau}\left(s_t, \xi_\tau, \eta_{i,\tau}; \Theta\right)$, was defined in the previous subsection. Each firm discounts its future profits according to a common discount factor β with a common information set. In the estimation, we set the discount factor equal to 0.85. Recall that we do not consider the issue of firm entry and exit in this study.

Investments incur costs. We approximate the investment cost $\phi\left(I_{i,t}; \theta\right)$ by the following polynomial series:

$$\phi\left(I_{i,t}; \theta\right) \equiv \sum_{r=1}^{R} \theta_r \cdot I_{i,t}^r \left\{I_{i,t} > 0\right\}\tag{6}$$

where the curly bracket $\{\cdot\}$ is the indicator variable, which takes the value of 1 when the statement inside the bracket is true, and 0 if otherwise. Note that θ is the set of parameters θ_r that are to be estimated. We employ a polynomial expansion with respect to $I_{i,t}$ to characterize the investment cost $\phi\left(\cdot\right)$.

Following Maskin and Tirole (1994; 2001), we consider a pure Markov perfect Nash equilibrium (hereafter MPNE). We restrict our attention to pure strategies and do not consider mixed strategies. The MPNE in this paper consists of a set of best-response strategies that govern investment decisions. An equilibrium is assumed to exist, the theorem of which is examined by Doraszelski and Satterthwaite (2003) in dynamic oligopoly models. In our modeling assumption, a Markov strategy for firm i describes the firm's behavior at time t as a function of the commonly observed state variables at time t. The Markovian assumption allows us to abstract from calendar time. We thus omit the time subscript hereafter, provided the omission does not cause confusion.

The value function V_i is the discounted sum of profits at the beginning of a period before the shocks are realized. It can be decomposed down into two components: the per-period payoff and the continuation value. Each firm uses the value function to determine its investment amount in the intertemporal optimization condition, where today's incremental cost incurred by making a unit of investment equals the present value of the benefit of cost reduction through capital accumulation. Let $I(s)$ be a set of investment strategies for all firms, whose i-th component is firm i's investment strategy $I_i(s)$. Note that the value function integrates out all the private and industry shocks in the per-period payoff function. Thus, firms base their investment strategy on the current state variables. Under the MPNE, we can rewrite the value function in Eq. (5) in the following recursive form:

$$V_i(s; I) = E_{(\xi,\eta)}\left[\left[\pi_i(s, \xi, \eta_i; \Theta) - \phi(I(s); \theta)\right] + \beta \int V_i\left(s'; I(s')\right) p\left(s'|I(s), s\right)\right], \qquad (7)$$

where the expectation operator $E_{(\xi,\eta)}[\cdot]$ is taken over ξ and η, conditional on s. Note that the i-th component of η is η_i, defined previously in this section. The profile $I(s)$ is a Markov perfect Nash equilibrium, if $V_i(s; I) \geq V_i\left(s; \widetilde{I}\right)$ and $\widetilde{I}$ differs from I only at the i-th element. We describe how to obtain an alternative policy $\widetilde{I}$ in the next subsection.

In the context of dynamic investment estimation, previous studies describe a policy function to illustrate that a firm's strategic investment behavior is responsive to its own state and rival firms' states. For example, Hashmi and Biesebroeck (2007) postulate that an R&D investment policy function can be described as a function of other firms' combined knowledge and the firm's own knowledge stock. In a study of the U.S. cement industry, Ryan (2006) also modeled a firm's physical investment in capacity adjustment as a function of the firm's own capacity and the sum of its competitors' capacities, in addition to the market productivity shock. We follow the treatment of the existing literature and assume that the investment policy is a function of the state variables in the following form:

$$I_i = g\left(k_i, \sum_{j \neq i} k_j, z\right) + \varepsilon_i^I, \qquad (8)$$

where ε_i^I is a private shock to firm i's investment, which follows a normal distribution $N\left(0, \sigma_{\varepsilon^I}^2\right)$, in which the variance parameter $\sigma_{\varepsilon^I}^2$ is to be estimated. We use a polynomial expansion to approximate the policy function $g(\cdot)$ as detailed in Section 4. If strategic considerations were not important in the firm's investment decision, we would expect the second term in $g(\cdot)$ to have no explanatory power.

3.4 Estimation Procedure

In this subsection, we describe the procedure for estimating the parameters of the dynamic investment model presented above. We adopt a two-step method proposed by BBL (2007), who use a simulation-based method to recover a firm's value function from the observed data. Their approach involves two stages. In the first stage, the firm investment policy function is recovered by regressing observed actions on the observed state variables. The product market profit function, along with the probability distributions of the three shocks ξ, u_i, and ε_i^I are also estimated at this stage. In the second stage, the dynamic parameters governing the cost of investment is estimated, such that the observed functions obtained in the first stage become optimal. The estimates are then used to simulate the model in order to assess the effect of the merger between Yawata and Fuji, which is discussed in Section 5.

The first stage involves the estimation of both the per-period profit function obtained from the product market and the investment policy function. The per-period profit function, which comprises demand and cost functions, is estimated outside the framework of the dynamic optimization problem. We first estimate three types of demand for steel of homogeneous quality in a static context. The use of market-level data in the study period from 1960 to 1979 uncovers demand elasticity with respect to price, $|\varepsilon_t|$. We address the endogeneity of price by using cost-side instruments. The demand estimates are used to obtain the marginal cost under the assumption that firms compete over quantities in the product market.

The policy function illustrates the investment action taken by a firm for any particular state vector. The theoretical model introduced previously in this section suggests that the policy function should be a function of the state variables. Thus, under the assumption that firms play an MPNE, a flexible estimation method should trace the true underlying investment policy function in response to the state vectors. Finally, we estimate the variance parameters in the probability distributions of ξ, u_i, and ε_i^I by using the residuals obtained above.

The second stage of the estimation procedure is concerned with recovering the set of investment-cost parameters, θ, which causes the policy function obtained in the first stage to become optimal. To do so, we evaluate a firm's value function by using the forward simulation procedure laid out by BBL (2007), which is as follows. Given the initial state s_{1960} and arbitrary values for the set of dynamic parameters θ_0, we draw the shocks ξ, u_i, and ε_i^I independently and randomly from the corresponding normal distributions. Notice that the variances of these normal distributions are already estimated in the first stage and that we use the actual value for z, a subset of the state variables. On the basis of the realized shocks, we calculate the amount of investment using Eq.(8) and derive demand and marginal cost functions to compute equilibrium outputs and per-period profits for the year of 1960 using Eq(3). We subsequently use the capital accumulation process to

determine the next period's state, s_{1961}. Following the same procedure, we compute the per-period payoff in the next year (1961) as $\pi\left(s_{1961}; \widehat{\Theta}\right) - \phi\left(I_{1961}; \theta_0\right)$, where $\widehat{\Theta}$ is a set of demand and cost parameters estimated in the first stage. We continue this process until the end of the study period (1979) and obtain the following present discounted profit for firm i:

$$V_i\left(s_{1960}|\theta_0\right) = E\left[\sum_{\tau=1960}^{1979} \beta^{\tau-t}\left[\pi_{i,\tau}\left(s_t; \widehat{\Theta}\right) - \phi\left(I_{i,\tau}; \theta\right)\right] |\theta = \theta_0\right], \tag{9}$$

where the expectation operator is taken over the future states. We run this forward simulation 1000 times and take the average to obtain a numerical estimate of $V_i\left(s_{1960}|\theta_0\right)$. Under the MPNE, the model stipulated here should hold at any arbitrary value on the initial state variables. We can thus construct an alternative equilibrium path as follows: we randomly draw the value a_j from a uniform distribution $[-0.1, 0.1]$ for each $j \in [1, ..., N_{1960}]$. We subsequently construct the initial state variables by replacing $s_{j,1960}$ by $(1 + a_j) s_{j,1960}$ for all j's and apply the forward simulation in the same manner applied for the case of s_{1960}. In the end, we derive 300 equilibrium paths for Eq.(9).

Finally, we employ a minimum distance estimator to estimate θ on the basis of the concept of MPNE. For the investment policy function $I\left(s\right)$ to be an MPNE strategy, the following inequality must hold for any firm i and state s: $V_i\left(s, I\left(s\right)|\theta\right) \geq V_i\left(s, \widetilde{I}|\theta\right)$, where $\widetilde{I}$ differs from I only at the i-th element, under the condition that the true dynamic parameter is θ. Using the same draws and initial states, we randomly draw firm i from $[1, ..., N_{1960}]$, and calculate $V_i\left(s, \widetilde{I}|\theta\right)$ for an alternative policy profile of $\widetilde{I}$. We obtain this alternative policy profile for the chosen i by randomly drawing the value a_i from a uniform distribution in the range from $[-0.1, 0.1]$ for each period, and replacing I_i with $(1 + a_i) I_i$. We then construct the following minimum distance estimator:

$$\widehat{\theta} = \arg\min_{\theta} \sum_{i,s,\widetilde{I}} \left[\min\left\{d_i\left(s, I\left(s\right)|\theta\right), 0\right\}\right]^2, \tag{10}$$

where $d_i\left(s, I\left(s\right)|\theta\right) = V_i\left(s, I\left(s\right)|\theta\right) - V_i\left(s, \widetilde{I}|\theta\right)$. The idea is that the estimator is calculated by penalizing the case where the value of $V_i\left(s, \widetilde{I}|\theta\right)$ is greater than that of $V_i\left(s, I\left(s\right)|\theta\right)$. As long as $I\left(s\right)$ is an MPNE strategy, this strategy should maximize firm i's present discounted profit. Notice that we simulate the evolution of the state vector for the period from 1960 to 1979, and do not extend the simulation beyond this period. This is primarily because, as Figure 1 illustrates, the steel industry appeared to enter a new phase of its evolution; firm investment activities slowed down as the market became satiated. We now report the estimation results in the next section.

4   Empirical Results

This section applies the estimation models described in the previous section to the annual frequency data set for the period from 1960 to 1979. We chose to start the sample in 1960, when Kobe — the smallest company in the data set — had a fully operational blast furnace and became an integrated steel maker. Including Kobe in this study helps us expand the data set.

We first discuss the estimation of the demand and marginal cost functions as well as the policy function. We then proceed to the estimation of the dynamic parameters associated with the investment cost. The summary statistics pertaining to the important variables used in the estimation appear in Table 1, and the data sources are presented in the Data Appendix. Section 5 uses the estimates reported in this section to assess the economic consequences of the 1970 merger.

Demand Estimates   We follow the literature regarding the homogeneous product demand model and estimate the inverse demand function of crude steel, $p_t\left(Q_t; z_t, \xi_t, \Theta^d\right)$. Demand estimation typically involves a functional-form assumption. The shape of the demand function determines the demand elasticity with respect to price and, thus, influences the marginal cost estimate. For example, under our assumption of Cournot competition with a constant marginal cost, a linear-demand specification imposes the LHS of Eq.(4) proportional to firm i's output quantity, while a log-linear specification restricts the LHS proportional to firm i's market share. We are therefore interested in comparing the implied marginal cost estimates from a variety of commonly used functional forms. Following Genesove and Mullin (1998), we estimate three different inverse demand functions of the linear, quadratic, and log-linear forms:

$$
\begin{aligned}
\text{Linear} \qquad & p_t = \alpha_0^L + \alpha_1^L z_t + \alpha_2^L Q_t + \xi_t^L \\
\text{Quadratic} \qquad & p_t = \alpha_0^Q + \alpha_1^Q z_t + \alpha_2^Q Q_t + \alpha_3^Q Q_t^2 + \xi_t^Q \\
\text{Log-Linear} \qquad & \ln\left(p_t\right) = \alpha_0^{LL} + \alpha_1^{LL} z_t + \alpha_2^{LL} \ln\left(Q_t\right) + \xi_t^{LL}
\end{aligned}
\tag{11}
$$

where α_B^A belongs to Θ^d, in which $A = \{L, LL, Q\}$ and $B = \{0, 1, 2, 3\}$, and ξ_t^A is the demand error for each specification. Two variables are used as exogenous demand shifters: z_t and the year dummy variables, which take a value of one for the years in the period after the first oil crisis of 1973, and zero for the remaining years. The second demand shifter is included in order to capture the extent to which the demand structure was altered in the post oil crisis period. The potential endogenous variables in (11) are p_t and Q_t. To correct for this possible endogeneity problem, we employ the two-stage least squared (2SLS) estimation. Regarding instruments, we use the prices of the major factor inputs used in steel making, namely, iron ore and heavy oil (both in terms of logarithms). We also use the average seaborne shipping distance of iron ore. Note that all iron ore was imported from neighboring countries such as the Philippines and later India because of the

demand for better quality. The data consist of the annual time series in the study period from 1960 to 1979.

Table 3 presents two broad columns of demand estimates. The first column is based on the ordinary least squared (OLS) method, and the second is based on the 2SLS method. Each column contains the three demand specifications presented in Eq.(11). The upper portion of Table 3 reports the estimates of the regression coefficients. Our inferences are based on heteroskedasticity-robust standard errors. All the results obtained indicate that the models fit the data well; the measure of the adjusted R^2 is above 0.9.

It is known that the 2SLS method can produce severely biased estimates if the instruments are weak. We thus check the explanatory power of the instruments, conditional on the included exogenous variables in the first stage of the 2SLS method. We obtain an F-statistic for each of the endogenous variables discussed above. Table 3 reports the average value of the F-statistics. We find that all the instruments used in this paper are not weak at the 99 % confidence level. The estimated coefficients in the table are obtained by regressing the dependent variable on the exogenous and fitted values of the endogenous variables.

All the specifications reported in Table 3 yield precise estimates of the demand shifters. The implied demand elasticity with respect to price is calculated for each specification on the basis of the obtained demand estimates. The elasticity is fairly elastic: its values range from 2.96 to 3.95. Comparison between the demand elasticities obtained from the OLS and 2SLS methods indicates the successful elimination of endogeneity from the positive correlation between steel output and demand shock: the mean value of the implied demand elasticity obtained from the 2SLS estimates is approximately 20% lower than those obtained from the OLS estimates. In the remainder of this paper, we use the log-linear form as the base specification of steel demand, because it achieves the highest log-likelihood concentrated with respect to a variance parameter. The other demand estimates make no qualitative change to the main empirical results discussed in the subsequent sections. Under the log-linear form, we estimate σ_ξ as 0.05, the value of which is used for the forward simulation.

Marginal cost Estimates   Using the demand estimates obtained in Table 3 and the first-order condition in Eq. (4), we calculate the marginal cost of steel production and estimate Eq. (2). Since we have no prior knowledge regarding the functional relationship between $k_{i,t}$ and the calculated $mc_{i,t}$, we use a polynomial expansion to approximate $f_t(\cdot)$. The empirical results presented here use a third order polynomial to approximate $f_t(\cdot)$, but there is almost no change in the minimand when we go from a third to a fourth order approximation.

Four estimation results are presented in Table 4. While with the first two specifications, we assume that the marginal cost error, $u_{i,t}$, follows i.i.d and apply the OLS estimation method to

the data, the remaining specifications allow for other types of error structures and use the feasible generalized least squared (FGLS) method. Specification (4-A) includes the firm- and year-specific components, v_i and ϖ_t, already introduced in Section 3.2. While (4-B) substitutes a random effect for v_i, we find that the Hausman-Wu test rejects this specification at the 99% confidence level. The paper thus focuses on the fixed-effect specifications. Specifications (4-C) and (4-D) allow for first-order autocorrelation, namely AR(1), in $u_{i,t}$, and (4-D) further incorporates additional heteroskedasticity in the error. Notice that the number of observations is smaller for (4-C) and (4-D) because we drop a year from the data for each firm to estimate the AR(1) coefficient. The table shows that the autocorrelation coefficient, which is common across all the firms, is estimated to be significant at the value of 0.51, and the Breusch-Pagan test did not reject the absence of heteroskedasticity. Nevertheless, all specifications yield precise estimates regarding the relationship between $mc_{i,t}$ and $k_{i,t}$. The estimates indicate that the averaged values in the elasticity of marginal cost with respect to its own capital are of similar magnitudes across the specifications in the range from -0.014 to -0.025. The estimates of firm-specific components indicate that the merger substantially improves production efficiency for the merging party. In comparison with the average estimates of the firm-specific effects in Yawata and Fuji, the table indicates that the merger enhanced the efficiency of Nippon Steel in the range of JPY 1329 to 2155 per ton of steel. To take the most conservative estimate of the efficiency gain from the merger, we employ (4-A) as the base specification for the paper's analysis.[9] Using (4-A), we estimate σ_u as 275 and use this value for the forward simulation, as discussed later in this section.

Estimates of Policy Function and Investment Cost   The next task is to characterize the policy function, which describes the equilibrium behavior of firms conditional on the state vector. To uncover the manner in which firms reacted to changes in the economic environment, we empirically estimate the policy function, $I(s)$, as being as flexible as possible from the observed investment decisions. Owing to the limited data set, we approximate the policy function by using a polynomial series estimator, $g(\cdot)$, in Eq.(8). The results presented here use up to a second-order polynomial-series estimator, but the results are qualitatively the same as those obtained by a third-order polynomial. The estimator includes the public fixed capital formation, firm i's own capital, the sum of the capital owned by the other firms, and their full interaction terms.

The results are summarized in Figure 2. The estimated investment policy function appeared to

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[9]Though not reported in the table, we also estimated the model that allows for the AR(1) coefficient to differ by firm. The averaged value of the autocorrelation coefficients is 0.502, and the rest of the estimates are of similar magnitude. Note that using the estimates from (4-C) and (4-D) imposes additional difficulty in the estimation of our dynamic model because each firm may infer private information about the other firms by observing past values of the marginal cost error.

have experienced considerable changes in 1970 when the merger took place. In order to conserve space, we present two panels from the respective years 1969 and 1971. The results for the other years in the study period are available from the authors upon request. Each panel in Figure 2 illustrates, conditional on z_t, a three dimensional relationship among $I_{i,t}$, $k_{i,t}$, and $\sum_{j \neq i} k_{j,t}$ in the region where the data are observed in each year. To more closely examine the estimated policy function, we illustrate cross-sectional views in Figure 3. The upper portion of Figure 3 shows the relationship between $I_{i,t}$ and $k_{i,t}$ for the years 1969 and 1971, while the lower portion presents the relationship between $I_{i,t}$ and $\sum_{j \neq i} k_{j,t}$ for the same years.

Figures 2 and 3 indicate that the 1970 merger resulted in substantial changes in the firms' investment behavior. Two observations are worth noting with respect to the estimated policy function. First, throughout the study period, the amount of capital investment by each firm increases with its own capital stock, except for Nippon Steel, which exhibited a negative relationship. Second, for all the steel makers under consideration, the correlation between investment and the sum of other companies' capital stocks was found to be positive prior to the merger but negative afterwards.

The first observation comes from the estimation results, which show that investment activity reinforces itself. As indicated in the upper left panel in Figure 3, a firm of larger scale (in terms of capital stock) invests more, leading to divergence in capital size across firms. This multiplier effect, however, appeared to diminish as the firm size became adequately large. Indeed, the upper-right panel of Figure 3 implies that the capacity size begins to stabilize for Nippon Steel.

The second observation offers an interesting insight regarding strategic interaction in the firms' investment decisions. The lower two panels in Figure 3 illustrate that firm investment activities were a strategic complement before the merger but became a strategic substitute afterwards. The nature of the strategic interaction observed in the estimated policy function appears to be consistent with the information obtained from trade journals.[10] It is known that under the booming steel demand, integrated steel makers engaged in fierce competition in terms of capacity expansion in the late 1950s and the 1960s. Indeed, the Ministry of Industry and International Trade (MITI), backed by several steel makers, made several attempts to cartelize the steel makers and coordinate their investment activities. Though all these attempts failed because small companies did not follow suit, competition in investment was never an issue in the industry circle after Yawata and Fuji consolidated their investments. While weaker competition in capital investment may have been due to the fact that steel demand began to be satiated (see Figure 1), this observation appears to agree with our finding that the firms' investment activities became strategic substitutes in the post-merger period.

The estimates for the dynamic parameters of investment cost are presented in Table 5. We

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[10]We thank Tsuyoshi Nakamura for bring this information to our attention.

estimate them through the minimum distance estimator in Eq. (10). This estimation procedure was also described in the previous section. Since we have no prior information regarding the investment cost function, we again employ a polynomial series expansion to estimate θ in Eq.(6). Table 5 shows a first-order, second-order, and third-order polynomial series with respect to the firm's investment amount. Since we formulate the investment cost as a linear function of its amount, the minimum distance estimator is formulated as a linear combination of θ. Note that the constant term in $\phi(\cdot; \theta)$ is not identified because the estimator is constructed by the difference in $\phi(\cdot; \theta)$. Three specifications shown in the table all imply that investment cost is regarded as approximately 10% of the value of investment per firm. For the sake of simplicity, we use Model (1) in the following analysis; however the paper's results change little when we use the other models in Table 5. The obtained estimates of investment cost play an important role when we calculate the welfare analysis associated with the merger.

Model Prediction   To obtain a sense of how the model fits the data, we compare the actual and predicted industry prices, outputs, market shares and capital stocks over the study period. We divide the period into two sub-periods: the pre-merger period from 1960 to 1969 and the post-merger period after 1969. We then compare the averages and standard errors for each of the periods. Table 6 shows the results of this comparison. The LHS of the table presents the prediction based on the base model introduced in this section, while the RHS presents the actual data, some variables of which were already introduced in Table 1. To save space, we list the market shares and capital stock of the merging and non-merging parties.

The predicted values in Table 6 are calculated in the same method used in the forward simulation when the initial state variables are the actual values of s_{1960}. To briefly review the method, using the estimates obtained above and conditional on the current state s_{1960}, we compute the firm's current investment by use of a realized private shock randomly drawn from the estimated normal distribution of $\varepsilon_{i,t}^I$, and Eq.(6). We then draw the realized demand and cost shocks from the respective estimated distributions of ξ_t^{LL} and $u_{i,t}$, and calculate the firm's marginal cost through Eq.(2). Using the cost estimates, we subsequently solve for an equilibrium with Eqs.(4) and (11) to obtain industry price and firm outputs for the year 1960. We accumulate the calculated investment to the respective firm's capital stock and use the result of the computation in the next period. We run this forward simulation 1000 times and present the average of the simulated values for each variable in Table 6.

The results show that the model explains the data well. Industry outputs and prices are predicted fairly accurately, and there is no significant bias in the market share prediction. Capital stocks appear to be underpredicted in the post-merger period from 1970 to 1979, particularly for the merging party. Since the goodness-of-fit measures for the demand, marginal cost, and investment

policy functions were all found to be reasonably well (discussed previously in this section), we believe that the finding of an underpredicted capital stock may well be attributed to simulation errors. While it is difficult for us to correct for this prediction bias, the results in Table 6 indicate that our estimates of the efficiency gains from the merger, which are discussed in the next section, are likely to be understated.

5 Economic Consequence of the 1970 Merger

This section comprises two subsections and assesses the economic consequences of the horizontal merger that took place between Yawata and Fuji in 1970. On the basis of the model and the estimates reported in the previous section, Section 5.1 evaluates the welfare tradeoff associated with the horizontal merger by comparing the counterfactual situation, in which no merger took place. The paper finds that the merger enhanced production efficiency and notably outweighed the deadweight loss resulting from the increase in market power.

The section also assesses the effectiveness of the structural merger remedies endorsed in the negotiation process between the J-FTC and the companies involved in the merger. The merger was approved under the condition that the merged party would transfer its capital equipment to two smaller companies, Kobe and Nihon Kokan. Section 5.2 performs simulation exercises to assess the welfare consequence of this divestiture and finds that the remedies reduced social welfare by constraining investments and increasing the marginal cost of production at the industry level. We conclude that the proposed remedies made little economic sense not only from the ex-post but also from the ex-ante perspectives of social welfare.

5.1 Economic Impacts of Merger

This subsection intends to assess the economic impacts of the merger. To conduct the assessment, we compare the merger outcome (as simulated in the previous section) with the no-merger outcome. The no-merger outcome is simulated by investigating what would have happened to the steel market had no merger taken place between Yawata and Fuji. Under this counterfactual scenario, we take the merger as exogenous and treat Yawata and Fuji as different business entities even in the 1970s. Thus, we assume that Yawata and Fuji independently decided their own outputs and investments on the basis of their own capital stocks, which continued to accumulate from the 1960s. Thus, the number of firms in the market, N_t, is assumed to be six throughout the period in the simulation procedure performed.

Figure 4 shows the effects of the merger on the industry outcomes by year. The figure contains the following four panels: price (4-a), marginal cost (4-b), capital stock (4-c), and social surplus

(4-d). Figure 5 presents the effects for both merging and non-merging parties. The panels in the upper row (from panels (5-a) to (5-d)) of Figure 5 indicate the merging party, and those in the bottom row (from panels (5-e) to (5-h)) indicate the non-merging party. To conserve space, we take the smallest integrated firm, Kobe, to represent the latter group of firms.[11] Each row contains four panels for the output, marginal cost, economic profit, and capital stock of the firm. For exhibition purposes, the upper row of Figure 5 shows the sums of Yawata and Fuji's outcomes in the 1960s, to facilitate comparison with those of Nippon Steel.

The straight line in each panel of Figures 4 and 5 indicates the ratio of the respective simulated outcome when the merger took place to the simulated outcome in the absence of the merger. We will discuss the implications of the dotted line in Section 5.2. A ratio higher (or lower) than one indicates that the merger had a positive (or negative) effect on the corresponding economic outcome. Thus, the ratio points to one in the pre-merger period of the 1960s.

The upper right panel of Figure 4 indicates that the merger did increase steel prices, but by a small margin of 0.3% on average. Although the merging firm, Nippon Steel, reduced its output from the no-merger level (as shown in Panel (5-a)), its exercise of market power was apparently restrained by the elastic crude demand reported in Table 3. We argued in Section 2 that an alternative source of steel supplied by the emerging minimills may have been accountable for this finding. As a result, consumer surplus in the post-merger period decreased by a mere 0.45% — or the annual equivalent of approximately USD 300 thousand — from the 1960 price.

Alternatively, the merger improved steel production efficiency. Panel (4-b) illustrates that the marginal cost at the industry level declined on average by 1.5% from the no-merger level. Nippon Steel benefitted most from the merger; its efficiency improved by more than 4% from the no-merger level (see Panel (5-b)). This efficiency gain comes not only from its capital accumulation but largely from the estimated firm-fixed components, as shown in Table 4. Indeed, panel (5-d) shows that Nippon Steel did, in fact, reduce its investment with its enlarged capital stock that resulted from the merger. This is a consequence of the estimated policy function discussed in Figure 3.

It is interesting to note that because of the nature of strategic substitutability in the firm investment behavior, and also because of the fact that Nippon Steel decreased its investment, Kobe gradually increased its capital investment as compared with the no-merger level (panel (5-h)). Though the magnitude was very small, this eventually contributed to Kobe's production efficiency, as shown in panel (5-f). In sum, the industry-level capital stock initially decreased but subsequently increased, as shown in panel (4-c). The initial decrease was due to the reduction in Nippon Steel's investment, and the later increase was due to the increase in Kobe's (and non-merging parties') investment.

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[11]Results pertaining to the other non-merging firms are available upon request.

As a consequence of this retrospective analysis, the 1970 merger was estimated to be profitable not only for the merging firm but also for the non-merging firms, and was, therefore, welfare-improving (see panel (4-d)). Nippon Steel saw its profits increase by more than 60% on average (see panel (5-c)), while the non-merging firms (or Kobe) by 24% (or 31%) (see panel (5-g)). However, the firms' benefits from the merger gradually subsided with the depreciation of capital.

5.2   Effectiveness of Merger Remedies

A considerable and increasing proportion of the mergers reviewed recently are approved after remedies have been offered, such as divestitures, provision of access or conduct commitments (see Leveque and Shelanski, 2004, for U.S. and EU experiences). Though remedies are an important tool and an opportunity for competition authorities to fix the competition problems generated by a merger, few studies empirically assess the effectiveness of merger remedies. This section performs such an analysis using the example taken from the 1970 steel merger.

The merger was approved under the condition that Yawata and Fuji would transfer 1.5% of their production facilities to Kobe and 0.3% to Nihon Kokan. This subsection uses a simulation method similar to the one used in the previous section and investigates what would have happened to the market and integrated steel makers had the merger been approved with no such remedies. An answer to this question also provides us with an assessment of whether and how divestiture effectively improved economic welfare.

The dotted line in Figures 4 and 5 displays the ratio of the simulated equilibrium outcome under the counterfactual situation where Yawata and Fuji merged in the absence of the remedies to the corresponding outcome without the merger. Hence, the difference between the straight and dotted lines indicates the effectiveness of the divestiture remedies under study. Two interesting findings emerged from the figures. First, steel prices would have risen owning to the imposition of the remedies. Second, production efficiency would have deteriorated by 0.3% with the merger remedies relative to the no-remedies level.

The remedies did appear to help the firms who received the assets from Nippon Steel. As indicated in panel (5-f), Kobe improved its marginal cost annually by 0.19%, because it obtained the divested asset. However, this asset transfer raised the industry-level marginal cost (see panel (4-b)) because Nippon Steel would have made much better use of such assets than did Nihon Kokan or Kobe (as shown in panel (5-b)). As a result, the remedies reduced industry output and therefore increased steel prices (but only by approximately JPY 40 per ton).

According to the estimated investment policy function depicted in Figure 3, the remedies would have provided Nippon Steel with conflicting incentives regarding its investment decision. On the one hand, the asset transfer would have encouraged the firm to invest more (see the upper-right

panel of Figure 3); on the other hand, active investment conducted by non-merging firms including Kobe would have discouraged Nippon Steel from investing in capital. In our estimation, the latter effect is found to be larger (as shown in panel (5-d)), so that the marginal cost of production would not have decreased more than that without the remedies (see panels (4-b) and (5-b)). Since the decline in the merging party's profit was more than the benefit received by the non-merging party (see panels (5-c) and (5-g)), social welfare would have decreased on average by 7.2% with the proposed remedies (see panel (4-d)). To conclude our ex-post analysis of the merger remedies, we found that while they succeeded in keeping the competitors viable, the merger remedies failed to maximize economic social welfare.

Note that in many industrial countries, merger reviews are required before a merger actually takes place. It is thus an interesting research question to examine merger remedies in terms of an ex-ante perspective based on the information available before the merger event. We attempt to answer this question by using the structural estimates obtained in Section 4 and the data available up to the year of 1969. The three items shown in Table 7 are sufficient for this analysis: elasticity of firm investment with respect to the firm's capital, investment elasticity with respect to the other firms' capital, and elasticity of marginal cost with respect to the firm's capital stock. The first two elasticities are obtained from Figure 3 and the last is obtained from Table 4: all are conditional upon the 1969 data. Table 7 indicates that transferring productive assets from the merging firms to Nihon Kokan and Kobe appeared to make little economic sense. Yawata and Fuji would have made more investments in the absence of the remedies. Indeed, Kobe would have invested more if the merging party had not transferred its assets as stipulated in the remedy proposal. Furthermore, the marginal cost estimates show that Yawata and Fuji produced steel as efficient as either Nihon Kokan or Kobe in 1969. Therefore, it appears from this final analysis that J-FTC would have exercised better judgment in terms of improving economic social welfare had it endorsed the proposed merger without the remedies.

6 Conclusion

This paper estimated a dynamic oligopoly model to evaluate the economic consequences of the horizontal merger that took place in 1970 between Yawata and Fuji. This merger created Nippon Steel, which has since remained the second largest steel producer in the world, after U.S. Steel at the time of the merger and now after Arcelor Mittal. In order to conduct policy experiments, it was necessary to determine all the parameters of the model, including the demand and cost functions, investment policy function, and distribution of exogenous shocks. Characterizing the relationship between the data generating process and the equilibrium played in the model was complicated by the fact that the model involved repeated interactions. We solved for an MPNE of the model by

using the method proposed by Ericson and Pakes (1995) and Bajari, Benkard, and Levin (2007).

Three important observations emerged from our estimation results. First, the obtained estimates implied that steel demand was fairly elastic with respect to price. This finding indicated that the price hike observed in the data were primarily due to shifts in demand; the merger would have left little room for the merged firm to exercise its market power. Second, the marginal cost estimates indicated that scale economies existed in capacity size. They also showed the existence of cost synergies associated with the merger (as implied by the firm-fixed effects). These results appeared to ensure that the merger entailed production efficiency. Finally, the estimates obtained from the policy function pointed out changes in the nature of strategic interaction in investment behavior among firms. The firms' capital investments strategically complemented one another prior to the 1970 merger. Once the merger took place, however, the investments altered to become strategic substitutes, implying that a firm responds by investing more when others invest less. We conjectured in the paper that the change in the nature of strategic interaction in investment behavior might have been accounted for by the fact that the Japanese steel industry entered a mature phase of its evolution.

On the basis of the obtained estimates, we first assessed the economic impacts of the horizontal merger in 1970. The simulation exercises indicated that the merger improved production efficiency not only for the merged party but also for the non-merged party, and thus enhanced economic social welfare. The non-merging party increased its efficiency because Nippon Steel reduced its investment in its capacity from the counterfactual no-merger level. The feature of strategic substitutability in investment would have made the non-merging firms respond by investing more in their own capacities. Under the restrained market power, the merger would have enhanced social welfare by an annual average of more than 40%, or equivalently USD 250 million.

Next, we evaluated the merger remedies of divestiture endorsed by the competition authority in the 1970 merger. The divestiture remedies stipulated that the merged party would transfer 1.8% of its production facility to two smaller competitors. The simulation results showed that while they helped the smaller firms remain viable competitors in the market, the proposed divestiture remedies failed to achieve the full efficiencies that should have been realized from the merger. Indeed, we found that the remedies would have undermined the industry-level production efficiency by half a percent, indicating that the remedies would have hurt social welfare by an annual amount of JPY 21 billion, or USD 70 million.

We also reported that the result of a welfare-improving merger based on the above retrospective analysis holds even in the ex-ante perspective, when we consider the remedies on the basis of the information available prior to the merger. Indeed, it appeared to make little economic sense for J-FTC to endorse the proposed remedies under the situation where the firms' investments

complemented each other strategically and thus increased with capacity size; production efficiency would have surely improved in the absence of the divestiture.

In this paper, we have shown that both the static and dynamic analyses agreed that the merger under study was welfare improving. Applying data pertaining to the Japanese steel industry in the 1960s and 1970s, our dynamic estimation model has provided us with additional useful insights regarding merger reviews, which are often required before a merger actually takes place. To assess the proposed remedies, this paper has suggested that the competition authority gain better knowledge of the structures of the marginal cost and investment policy functions of the firms involved in the merger under investigation. These estimates, along with demand estimates, are available from the static estimation framework, and may help us easily evaluate the welfare consequence of the remedies, as we did in this paper.

A Data Appendix

Annual data on the industry- and firm-level output data were obtained from Japan Iron and Steel Federation (1960-1980). The annual price data for domestically produced crude steel were taken directly from companies' semiannual financial reports (1960-1980). We found that the price level did not vary widely across firms, and hence, Yawata's crude steel prices in the 1960s and Nippon Steel's prices in the 1970s were used for the estimation. This price was adjusted by the manufactured goods WPI to a constant 1960 Japanese yen.

Two input prices were used in the paper: data on iron ore and heavy oil were taken from the Bank of Japan (1960-1980). Data on the average seaborne shipping distance of iron ore, the variable that is used as an instrument for the demand estimation, were obtained came from Japan Iron and Steel Federation (1960-1980).

Our measure of firm-level capital stock is the firm-level physical fixed production asset, taken from companies' semiannual financial reports (1960-1980). From the data on capital stock, we constructed the annual amount of firm-level investment. Both capital stock and investment data were converted from book value to market value by following the method proposed in Ogawa and Kitasaka (1998). We used the national wealth survey of 1960 to obtain the average age of each physical asset in the Japanese steel industry. The annual depreciation rate of 0.0805 was used, the value of which was estimated by Ogawa and Kitasaka (1998). Finally, investment and capital stock were adjusted by the manufactured goods WPI to a constant 1960 Japanese yen.

References

[1] Bajari, P., C.L. Benkard, and J. Levin, 2007, "Estimating Dynamic Models of Imperfect Competition," *Econometrica*, 75(5): 1331-1370.

[2] Berry, S., and A. Pakes, 1993, "Some Applications and Limitations of Recent Advances in Empirical Industrial Organization: Merger Analysis," *American Economic Review*, 83(2): 247-252

[3] Chen, J., 2008, "The Effects of Mergers with Dynamic Capacity Accumulation," *International Journal of Industrial Organization*, forthcoming.

[4] Compte, O., F. Jenny, and P. Rey., 2002, "Capacity Constraints, Mergers and Collusion," *European Economic Review* (46): 1-29.

[5] Davies, S., and B. Lyons, 2008, *Mergers and Merger Remedies in the EU: Assessing the Consequences for Competition*, Edward Elgar Publisher, U.K.

[6] Doraszelski, U., and M. Satterthwaite, 2007, "Computable Markov-Perfect Industry Dynamics: Existence, Purification and Multiplicity," *mimeo*, Harvard University.

[7] Ericson, R., and A. Pakes, 1995, "Markov-Perfect Industry Dynamics: A Framework for Empirical Work," *Review of Economic Studies*, 62(1): 52-82.

[8] Farrell, J., and C. Shapiro, 1990, "Horizontal Mergers: An Equilibrium Analysis," *American Economic Review*, 80(1): 107-126

[9] Hashmi, A.R. and J.V.Biesebroeck, "Market Structure and Innovation: A Dynamic Analysis of the Global Automobile Industry," *mimeo*, University of Toronto.

[10] Genesove, D., and W.P. Mullin, 1998, "Testing Static Oligopoly Models: Conduct and Cost in the Sugar Industry, 1890–1914," *Rand Journal of Economics*, 29(2): 355-377.

[11] Leveque, F., and H. Shelanski, 2004, *Merger Remedies in American and European Union Competition Law*, Edward Elgar Publisher, U.K.

[12] Motta, M., M. Polo, and H. Vasconcelos, 2002, "Merger Remedies in the European Union: An Overview," *mimeo*.

[13] Mullin, G.L., J.C. Mullin, and W.P. Mullin, "The Competitive Effects of Mergers: Stock Market Evidence from the U.S. Steel Dissolution Suit," *Rand Journal of Economics*, 26(2): 314-330

[14] Nakamura, T. and H. Ohashi., 2008a, "Technology Adoption, Learning by Doing, and Productivity: A Study of Steel Refining Furnaces," *Journal of Industrial Economics*, LVI(3): 51-80.

[15] Nakamura, T. and H. Ohashi., 2008b, "Effects of User Innovations on Industry Growth: Evidence from Steel Refining Technology," *mimeo*, University of Tokyo.

[16] Nishiwaki, M., 2007, "A Dynamic Analysis of Horizontal Mergers: The Case of the Japanese Cement Industry," *mimeo*, Hitotsubashi University

[17] Ogawa, K., and S. Kitasaka, 1998, *Asset Markets and Business Fluctuations — An Empirical Analysis of Modern Japanese Economy*, Nippon Keizai Shimbun Sha (in Japanese).

[18] Ohashi, H., 2005, "Learning by Doing, Export Subsidies, and Industry Growth: Japanese Steel in the 1950s and 1960s," *Journal of International Economics*, 66: 297-323.

[19] Olley, G.S., and A. Pakes, 1996, "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64: 1263-1298.

[20] Oster, S., 1982, "The Diffusion of Innovation among Steel Firms: The Basic Oxygen Furnace," *Bell Journal of Economics*, 13(1): 45-56

[21] Peters, C., 2006, "Evaluating the Performance of Merger Simulation: Evidence from the U.S. Airline Industry," *Journal of Law and Economics*, XLIX: 627-649.

[22] Pesendorfer, M., 2003, "Horizontal Mergers in the Paper Industry," *Rand Journal of Economics*, 34(3): 495-515.

[23] Tekko Shimbun Corp., 1960-1980, *Almanac on Steel*, Tokyo.

[24] Whinston, M., 2006, *Lectures on Antitrust Economics*, MIT Press, Cambridge.

[25] Williamson, O.E., 1968, "Economies as an Antitrust Defense: The Welfare Tradeoffs," *American Economic Review*, 58(1): 18-36.

[26] Yamawaki, H., 1984, "Market Structure, Capacity Expansion, and Pricing: A Model Applied to the Japanese Iron and Steel Industry," *International Journal of Industrial Organization*, 2: 29-62.

TABLE 1

Summary Statistics for Important Variables
Japanese Steel from 1960 to 1979

		Pre-Merger 1960-69	Post-Merger 1970-79
Price (in JPY per ton)	Average	42991 (2983)	62972 (16744)
Output (in Million tons)	Average	34.15 (16.80)	80.56 (7.69)
	Annual Growth Rate (%)	18.16	2.15
Capital Investment (in 100 billion JPY)	Merging Party		
	Average	0.99 (0.67)	1.46 (0.78)
	Share (%)	45.21	30.52
	Non-merging Firm		
	Average	0.30 (0.20)	0.77 (0.29)
	Share (%)	13.70	17.37
Capital Stock (in 100 billion JPY)	Merging Party		
	Average	4.40 (1.49)	12.27 (1.82)
	Share (%)	50.88	39.60
	Non-merging Firm		
	Average	1.11 (0.49)	4.82 (1.31)
	Share (%)	12.28	15.10

Notes:
Standard Error of the estimate is shown inside parenthesis.
Price, capital investment and stock are in terms of 1960 price.
The merging party is the sum of Yawata and Fuji in the 1960s, and Nippon Steel in the 1970s.
Values in non-merging firm in the table is the firm average of Nihon Kokan, Kawasaki, Sumitomo, and Kobe.

TABLE 2
Market Shares of Steel Production:
Impact of the 1970 Merger

1969	%	1971	%
Yawata	0.25	Nippon Steel	0.45
Fuji	0.23		
Nihon Kokan	0.18	Nihon Kokan	0.19
Kawasaki	0.16	Kawasaki	0.16
Sumitomo	0.14	Sumitomo	0.14
Kobe	0.04	Kobe	0.06
HHI	1946		2874
Steel Production For the six firms (Million ton)	62.549	Steel Production For the five firms (Million ton)	62.398

TABLE 3

Demand Estimates

Variables	OLS			2SLS		
	Linear	Quadratic	Log-linear	Linear	Quadratic	Log-linear
Quantity	-3.15 [a]	-5.04 [b]		-3.62 [a]	-4.88	
	(5.082)	(1.979)		(0.546)	(2.349)	
Quantity squared		1.86			1.26	
		(1.877)			(2.287)	
logarithm of quantity			-0.23 [a]			-0.25 [a]
			(0.04)			(0.037)
Government expenditure	2.95 [a]	2.92 [a]	4.82 [a]	3.09 [a]	3.07 [a]	4.96 [a]
	(0.199)	(0.201)	(0.314)	(0.210)	(0.216)	(0.321)
intercept	4.51 [a]	4.89 [a]	14.52 [a]	4.65 [a]	4.90 [a]	14.90 [a]
	(0.200)	(0.432)	(0.613)	(0.212)	(0.499)	(0.635)
Number of observations	20	20	20	20	20	20
Adjusted R-squared	0.951	0.951	0.952	0.947	0.947	0.951
1st stage F-stat.	-	-	-	64.26 [a]	64.24 [a]	82.15 [a]
log-likelihood	-187.78	-187.05	32.17	-188.39	-187.72	31.92
Elasticity w.r.t price	3.41	3.76	4.31	2.96	3.06	3.95

Notes:

Subscripts a and b indicate significance at the 99- and 95-confidence levels.

Standard Error of the estimate is shown inside parenthesis. Demand function is specified in Eq. (11) in the text. The year dummy variables are included for the period after the first oil crisis of 1973, the estimates of which are not reported in the table. For presentation purpose, the variables of Quantity and Quantity squared are divided by 1.0e+04, 1.0e+12, respectively. The variable of Government expenditure for the log-linear specification is divided by 1.0e+05, and intercepts for the linear and quadratic specifications are multiplied by 1.0e+04. The instruments used for Quantity and Quantity squared in 2SLS are prices of iron ore and heavy oil (both in logarithms) and the average seaborne shipping distance of iron ore. Elasticity w.r.t price is the average value of annual demand elasticities with respect to price in the period from 1960 to 1979.

TABLE 4

Marginal-cost Estimates

	OLS		FGLS	
	(4-A)	(4-B)	(4-C)	(4-D)
capital stock	-538.15 [b]	-1407.66 [a]	-360.47	-516.76 [b]
	(195.88)	(113.76)	(187.36)	(163.92)
capital stock^2	67.47 [b]	151.26 [a]	47.37 [c]	61.26 [b]
	(25.11)	(17.93)	(24.15)	(22.03)
capital stock^3	-3.73 [a]	-7.21 [a]	-2.52 [b]	-2.92 [b]
	(1.01)	(0.83)	(0.97)	(1.01)
Firm-specific component:	Fixed	Random	Fixed	Fixed
Nippon	-1878.05	-	-2498.24	-2409.20
Fuji	-356.63	-	-64.21	-52.31
Yawata	-742.04	-	-553.37	-455.95
Nihon Kokan	141.41	-	470.27	464.79
Kawasaki	252.16	-	628.52	604.31
Sumitomo	297.41	-	702.08	667.44
Kobe	797.38	-	1314.95	1180.93
Number of Observations	110	110	103	103
Wu-Hauseman test	-	60.37 [a]	-	-
Heteroskedastic residual	No	No	No	Yes
Breusch-Pagan tests	3.38	0.97	1.05	-
AR(1) coefficient	-	-	0.508	0.508
Elasticity w.r.t capital stock	-0.024	-0.053	-0.014	-0.018

Notes:
Subscripts a, b, and c indicate significance at the 99-, 95-, and 90-confidence levels.
Standard Error of the estimate is shown inside parenthesis.
All specifications include year-specific effects. Wu-Hausman test rejects the random effect specification
 (4-B). Breusch-Pagan tests would not reject the absence of heteroskedasticity. The AR(1) coefficients
 are estimated, which are assumed to be common across firms. Elasticity w.r.t capital stock is the
average of annual elasticities of firm marginal cost with respect to capital stock in the period from
1960 to 1979.

TABLE 5

Investment-cost Estimates

	(1)	(2)	(4)
I	0.156 [a]	-0.086 [a]	-0.101 [a]
	(0.005)	(0.008)	(0.029)
I^2		0.126 [a]	0.145 [a]
		(0.005)	(0.031)
I^3			-0.004
			(0.005)
No. Obs	300	300	300

Notes:

Subscript a indicates significance at the 99-percent significance level.

Standard Error of the estimate is shown inside parenthesis.

TABLE 6

Model Prediction

	Prediction		Actual	
	Pre-Merger 1960-69	Post-Merger 1970-79	Pre-Merger 1960-69	Post-Merger 1970-79
Industry Output	35.2	80.8	34.2	80.6
(in M ton)	(15.3)	(16.9)	(16.8)	(7.7)
Price	43007	63354	42991	62972
(in JPY per ton)	(2986)	(16910)	(2983)	(16744)
Merging Party				
Market share	48.5	38.7	48.9	42.3
(%)	(0.8)	(4.9)	(3.8)	(1.7)
Capital stock	4.1	8.8	4.4	12.3
(in 100 B JPY)	(1.4)	(0.6)	(1.5)	(1.8)
Non-Merging Party				
Market share	51.5	61.3	51.1	57.7
(%)	(0.8)	(4.9)	(3.8)	(1.7)
Capital stock	4.6	16.0	4.4	19.3
(in 100 B JPY)	(2.2)	(3.5)	(2.0)	(5.3)

Notes:
Standard Error of the estimate is shown inside parenthesis.
Merging party are the sum of Yawata and Fuji in the 1960s, and Nippon Steel
 in the 1970s. Non-merging party are the sum of Nihon Kokan, Kawasaki,
Sumitomo, and Kobe. JPY is in terms of 1960 price.

TABLE 7

Ex-ante examination of Merger Remedies
Estimated Elasticities from 1969

	Elasticities of $I_{i, 1969}$ w.r.t		Elasticities of $mc_{i, 1969}$ w.r.t.
	$k_{i, 1969}$	$\Sigma k_{j, 1969}$	$k_{i, 1969}$
Yawata	1.332	0.233	-0.018
Fuji	1.135	0.525	-0.018
Nihon Kokan	1.092	0.565	-0.018
Kawasaki	0.986	0.654	-0.017
Sumitomo	0.852	0.755	-0.016
Kobe	0.396	1.043	-0.009

Notes:
Elasticities of $I_{i, 1969}$ are obtained from the estimates from the investment policy function (as shown in Figures 2 and 3), while elasticities of $mc_{i, 1969}$ are from Table 4. The company names are in order of market share in 1969.
Nihon Kokan and Kobe, indicated in bold, received capital equipment from Yawata and Fuji, also indicated bold.

FIGURE 1
Evolution of Capacity Sizes:
Blast furnace, Refining Furnaces (in million tons)
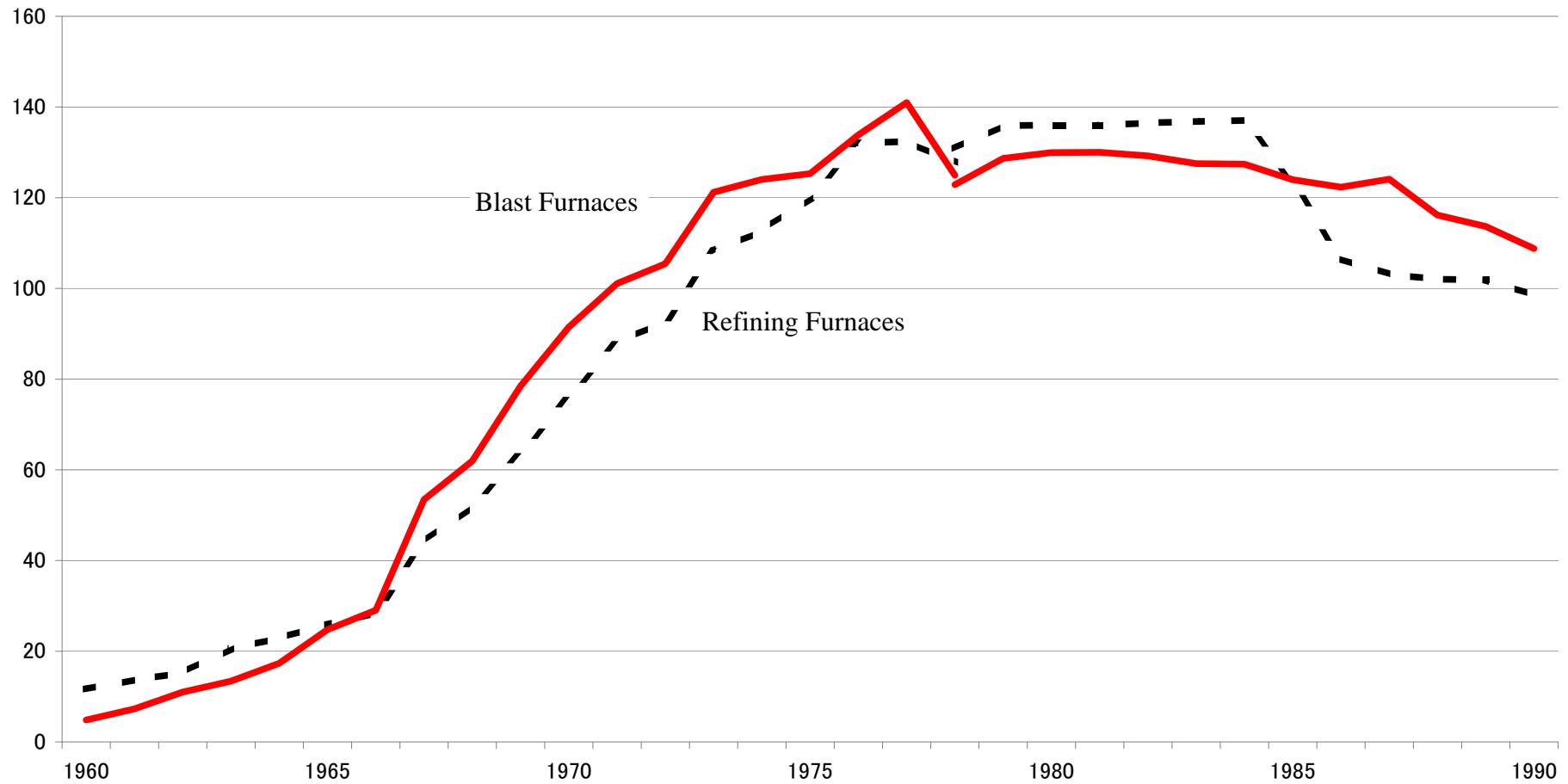
Note: Discontinuities in 1978 are due to changes in measurement unit reported in Japan Iron and Steel Federation (1960-1980).

FIGURE 2

Estimated Investment Policy Function
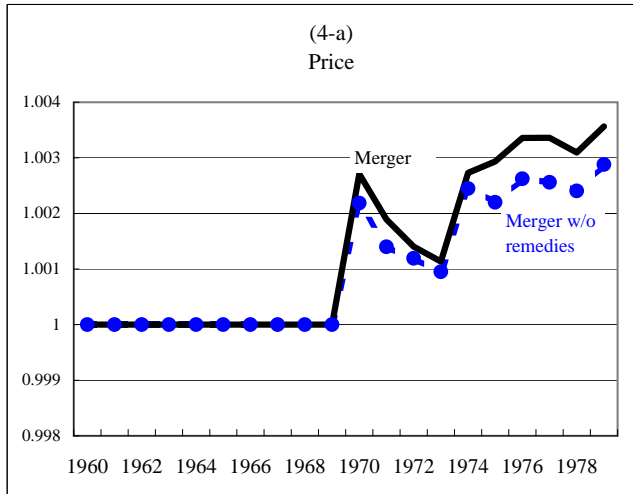### Industry Level of 1969 and 1971

1969
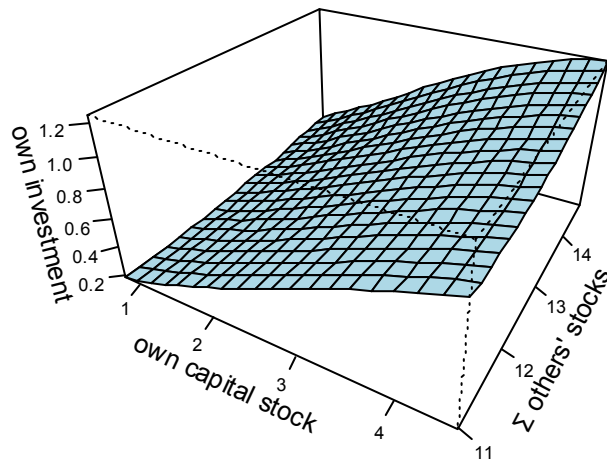
1971
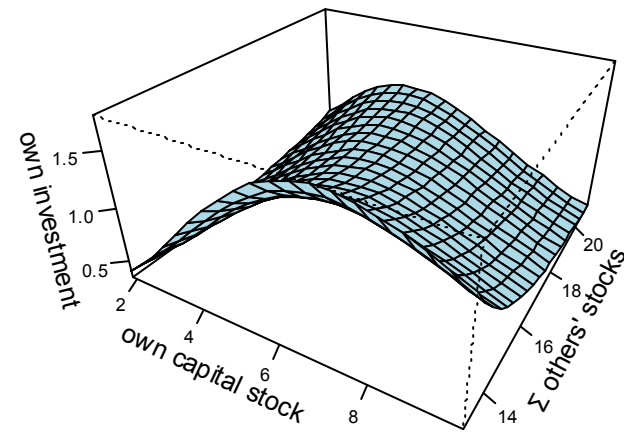
100 billion JPY
(in 1960 price)

FIGURE 3

Estimated Investment Policy Function
Firm Level of 1969 and 1971
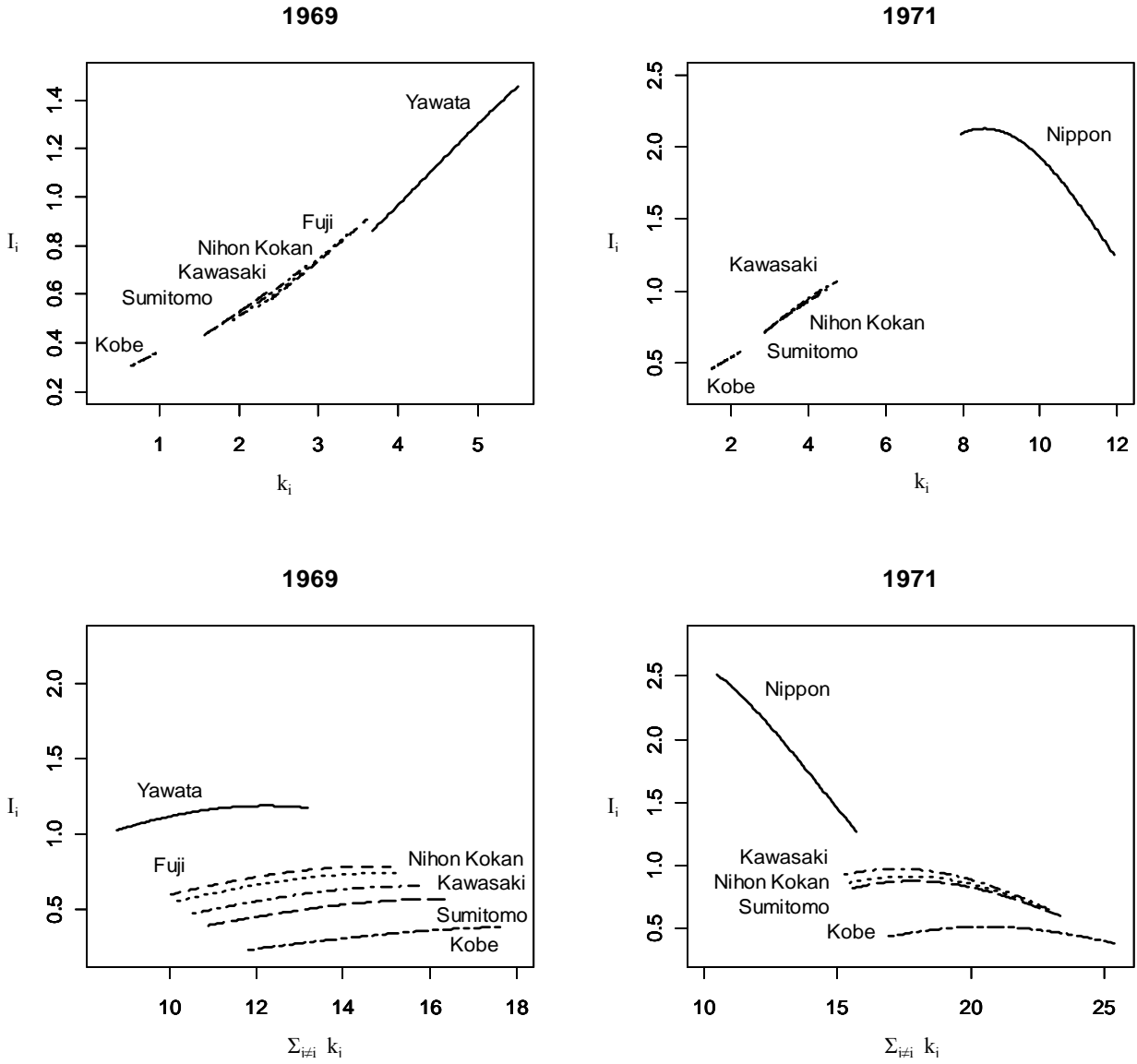
100 billion JPY
(in 1960 price)

FIGURE 4

Impacts of Merger (straight line) and Merger Remedies (dotted line) on Industry Outcomes:
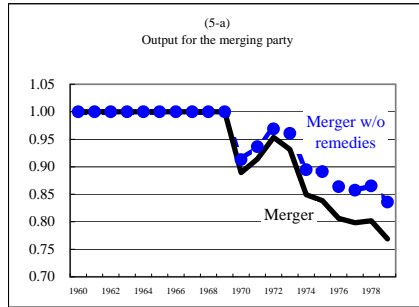
Comparison with the absence of Merger
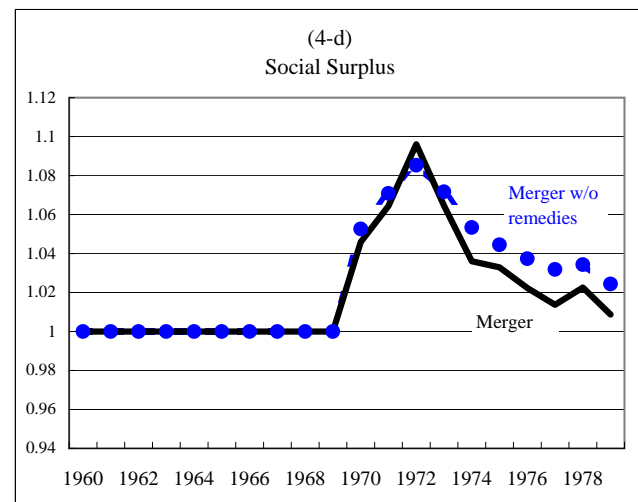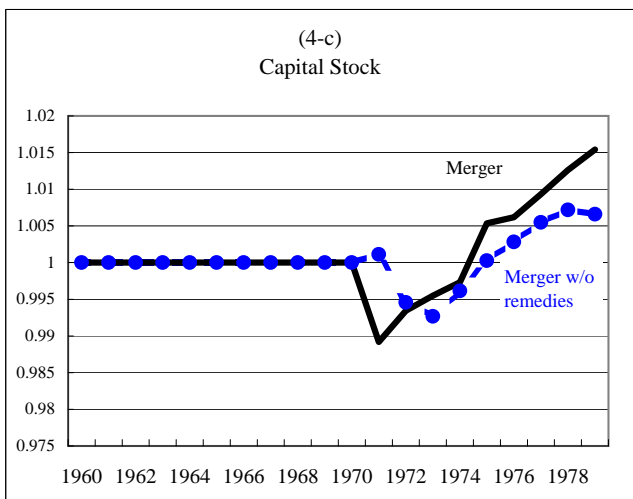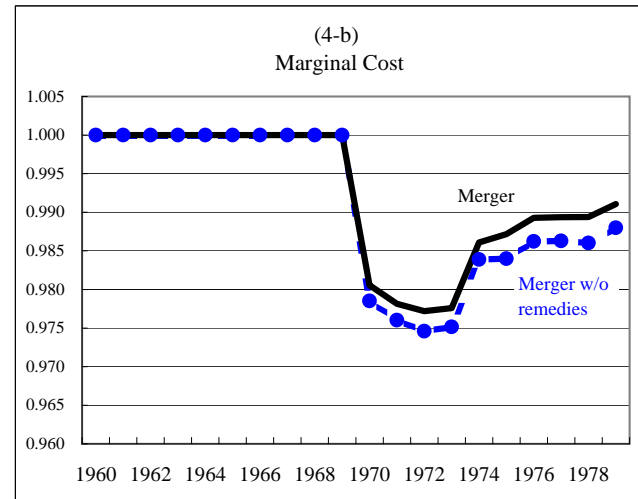
(4-a)
Price

(4-b)
Marginal Cost

(4-c)
Capital Stock

(4-d)
Social Surplus

Notes:

The straight line in each figure is the ratio of corresponding economic outcome under the merger relative to that in the absence of merger.

The dotted line is the ratio of corresponding economic merger outcome without the remedies to the outcome in the absence of merger.
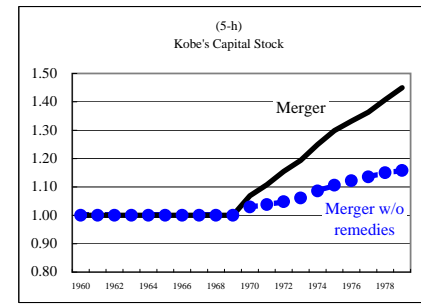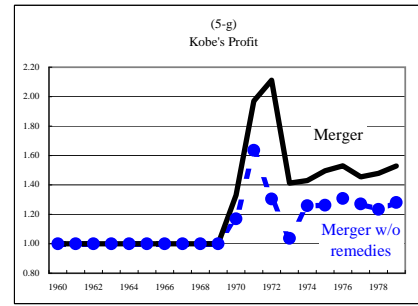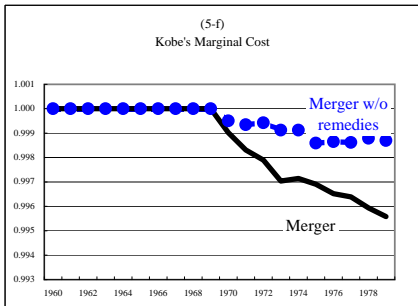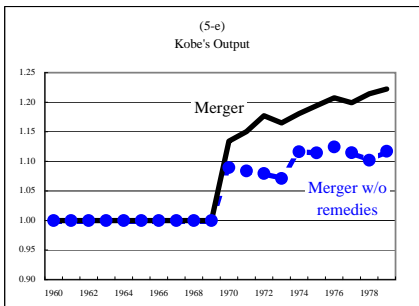
FIGURE 5

Impacts of Merger (straight line) and Merger Remedies (dotted line) on Economic Outcomes for Selected Firms

Comparison with the absence of Merger

Merging Party (Yawata and Fuji, and Nippon Steel)

(5-a) Output for the merging party

(5-b) Marginal Cost for the merging party

(5-c) Profit for the merging party

(5-d) Capital Stock for the merging party
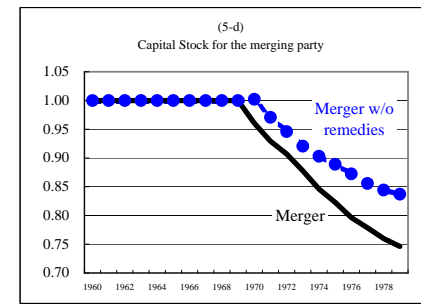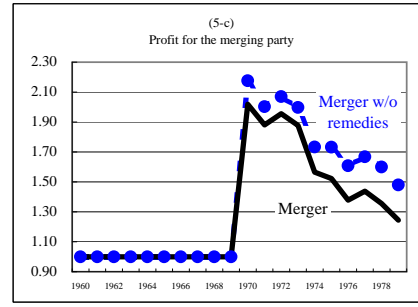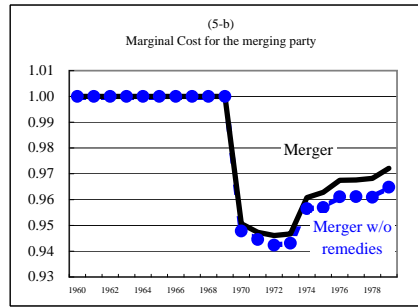
Kobe (as representing the non-merging firms)

(5-e) Kobe's Output

(5-f) Kobe's Marginal Cost

(5-g) Kobe's Profit

(5-h) Kobe's Capital Stock

Notes:
The straight line in each figure is the ratio of corresponding economic outcome under the merger relative to that in the absence of merger.
The dotted line is the ratio of corresponding economic merger outcome without the remedies to the outcome in the absence of merger.