Are Losers Picked? An Empirical Analysis of Capacity Divestment and Production Reallocation in the Japanese Cement Industry*

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Abstract

As demand in an industry shrinks, pressure for the reduction of capacity arises. Against this background, a key issue is whether plants which, from an efficiency perspective, should reduce output or close down in fact do so. Focusing on the Japanese cement industry, this paper empirically examines whether less efficient plants reduce capacity, and analyzes the presence and extent of production misallocation resulting from capacity divestment. We find that less efficient firms are not more likely to reduce capacity than more efficient firms; however, less efficient plants within a multi-plant firm are more likely to reduce capacity than more efficient plants. In addition, conducting an experimental exercise, we find that this divestment pattern has lead to a substantial drop in industry-wide allocative efficiency. The experimental exercise further reveals that it is the misallocation of production across firms that accounts for the largest part of the drop in allocative efficiency. This result suggests that the presence of multi-plant firms can help to alleviate inefficiencies arising in a period of industry decline.

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Keywords: declining industry, capacity divestment, production reallocation, cement producing plants

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I Introduction

In declining industries, as demand shrinks, pressure for the reduction of capacity arises. Firms in such industries are forced to reduce production capacity in order to remain profitable or, in the extreme case, to exit altogether. An important issue from the viewpoint of economic efficiency and public policy in this context is whether in these industries, it is the “losers” that are “picked,” that is, whether it is less efficient plants that reduce their production capacity or exit altogether (Peck, Levin and Goto 1987).

To assess the outcome, it is usually compared with the situation that would prevail if there were a social planner, or if a market were perfectly competitive. A social planner would choose plants based on their efficiency to reduce output as demand shrinks. That is, the capacity of less efficient plants would be reduced in the earlier stages of the demand decline and more efficient plants would continue to maintain their production capacity. The same pattern of contraction of industry capacity would be observed in a perfectly competitive market in which “losers” (less efficient plants) are selected through the market mechanism.

In an imperfectly competitive market, however, the outcome may differ from that achieved by a social planner or in a competitive market, because the size of a plant or firm may be a key determinant of the decision to reduce capacity. Ghemawat and Nalebuff (1985, 1990) in their simple model for example show that, in an oligopoly, small plants can have a strategic advantage over, and maintain production capacity longer than, larger plants. An important implication of the theoretical result is that capacity reduction decisions are not necessarily governed by plants’ efficiency. In other words, there is the possibility that more efficient plants cut their capacity more than their smaller rivals.

However, the result that plant size may act as an important determinant of the pattern of industry contraction applies only to the simplest of situations and not necessarily to more complex ones. As Whinston (1988) has shown, introducing a
multi-plant into the setting, for example, can dramatically complicate the capacity withdrawal decision problem, so that it is difficult to obtain a clear prediction for capacity reduction behavior. That is, even in a relatively simple multi-plant setting in which there is one firm with two plants and one single-plant firm, it is not possible to make any generalizations of Ghemawat and Nalebuff’s simple rule that are based on plant (or firm) size, since the smaller firm will not necessarily maintain its level of production capacity and the smallest plant does not necessarily survive.

In this paper, with this theoretical ambiguity in mind, we examine capacity reduction behavior in an oligopolistic market in the real world. More concretely, we examine empirically the impact of plant and firm characteristics on capacity divestment decisions and measure the magnitude of the inefficiency of production reallocation as a result of such divestment. Our empirical analysis addresses the following two questions. The first concerns whether any inefficiency in the capacity divestment pattern can be observed in the sense that more efficient plants (or firms) reduce their capacity more than less efficient plants (or firms). The second question concerns how the resulting production allocation differs from the optimal production allocation of a social planner. To answer these questions, we take a detailed look at capacity divestment behavior during the decline of a specific industry, namely the Japanese cement industry.

The Japanese cement industry provides a good case study to examine the capacity divestment problem in an imperfectly competitive market. The demand for cement mainly depends on private and public investment in construction, which has been declining since the burst of Japan’s bubble economy in the early 1990s. Along with this decline in demand, cement firms have been forced to reduce the capacity of their plants. Another important feature of the cement industry in addition to the decline in demand is that the number of firms operating in Japan is relatively small, so that the strategic interaction among cement firms plays an important role. A further important
feature of the cement industry is the presence of multi-plant firms, which means that we can also investigate the impact of the characteristics of other plants within the same multi-plant firm on capacity reduction decisions for a particular plant.

The results of our empirical analysis to examine the first question can be summarized as follows. We find that the effects of differences in firm size and efficiency are not statistically significant and not substantial in size. On the other hand, differences in plant efficiency and in plant size do have an influence on the divestment probability. What these results suggest is that when firms are under pressure to divest, and they have several plants under their control, they pick less efficient plants in their choice set to reduce capacity. To this extent, multi-plant firms contribute to the efficient industry contraction. However, our results also suggest that less efficient firms do not necessarily reduce production capacity more than efficient firms. Such inefficient divestment pattern will lead to a loss in welfare.

In order to address the second question, we quantify the extent of production misallocation caused by the divestments in the industry. We conduct an experimental analysis to compare the observed production allocation and the optimal allocation of a social planner. Our experiment shows that allocative efficiency, which is defined as the ratio of the optimal allocative efficiency to the actual efficiency, dropped by up to 18-percentage points in the 13 years period we examine. Further, we find that the largest part of this efficiency drop can be explained by the misallocation of production across firms.

This paper has the following four important features. First, this is one of only a handful of studies on industry contraction. Since the early works by Ghemawat and Nalebuff (1985) and Fudenberg and Tirole (1986), surprisingly few studies have been conducted on declining industries, despite the fact that almost all developed nations have declining sectors and the question how to promote capacity reduction in such sectors is a pressing policy issue. This study adds new empirical findings to the literature.
Second, this paper highlights the role of differences in plant characteristics within and between firms in the decision to reduce capacity. This makes our research distinct from previous studies (e.g., Lieberman 1990, Deily 1991, and Gibson and Harris 1996). Our finding emphasizes the importance of including these two differences in characteristics in investigating plant capacity withdrawal. Third, in contrast with previous empirical studies, we use an explicit measure of plant efficiency. Instead of using proxy variables, we estimate individual plant efficiency through the production function and examine its impact on capacity reduction as if plant efficiency was observed. To obtain reliable estimates of plant efficiency, we place only a few restrictions on the production function by using a nonparametric regression model. Fourth, we quantify the welfare cost associated with any misallocation of production in response to declining demand in an oligopolistic industry. Our experimental exercise compares the actual production allocation and the optimal one. The difference between these two outcomes can be regarded as the extent of production misallocation in the industry. This misallocation caused by divestments, if present, can be understood as a type of welfare cost. Our research is the first attempt to partly identify the cost of production misallocation in a declining industry.

The remainder of the paper is organized as follows. Section II reviews previous theoretical and empirical studies on divestment behavior in declining industries. Section III then provides a brief overview of the cement industry in Japan and the cement production process, while Section IV provides a description of the data used in this study. Next, Section V presents the empirical procedure employed. To obtain plant-specific efficiency, which we cannot observe, we estimate it through the production function. Using the estimate of plant level efficiency, we then examine the impacts of plant and firm characteristics on divestment behavior. The empirical results are presented in Section VI, before Section VII examines the efficiency of the actual reallocation of production when compared with the optimal production allocation of a social planner.
Section VIII concludes.

II Previous Studies

In this section, we provide a brief review of previous theoretical and empirical studies on declining industries. The best known model of declining industries is provided by Ghemawat and Nalebuff (1985; hereafter G&N 1985). Ghemawat and Nalebuff consider the case where two plants compete in Cournot fashion, demand is declining monotonically, the efficiency level of the plants is identical and common knowledge, but the size of the plants differs, and production is all-or-nothing (plants either continue to operate at full capacity or exit the industry).\(^1\) They show that, under these assumptions, the order of exit is determined by plant size: the larger one exits first. The reason is that the smaller plant has a strategic advantage since it can be a profitable monopolist over a longer period of declining demand.\(^2\)

An important implication of the G&N (1985) model is that the exit order may be determined only by plant size even if efficiency is heterogeneous.\(^3\) For instance, if the larger plant is the more efficient one (which is naturally assumed in a Cournot oligopoly), it exits first, while the inefficient plant remains in the market. From a social welfare perspective, it would be better for society if the larger plant survived longer than the smaller plant unless the tenure of the monopoly of the smaller plant is sufficiently long and the total welfare in the monopoly of the smaller plant does not

\(^1\)The model is easily extended to a situation with more than two plants and the efficiency level of plants differs to some extent.

\(^2\)Multiple equilibria can arise at the first date when duopoly profit goes to less than zero. In one equilibrium the larger plant exits earlier, but in the other equilibrium the smaller plant exits first. However, the larger plant equilibrium is not trembling hand perfect. If the smaller plant missed its exit date and failed to leave immediately, the larger plant’s plan is no longer optimal.

\(^3\)They also consider the effect of plant-specific efficiency, when this is not identical, on the exit order and show that the condition under which the more efficient plant can outlast the less efficient one. However, to outlast the smaller rival, the larger plant needs a huge cost advantage against the smaller rival.
exceed that achieved in the monopoly of the larger plant.\textsuperscript{4} In contrast to a perfectly competitive market, there is the possibility of a welfare loss due to declining demand.

Extensions of the G&N (1985) model go in two directions. First, Ghemawat and Nalebuff (1990; hereafter G&N 1990) extended their original G&N (1985) model to allow for incremental capacity reductions rather than all-or-nothing exit decisions. The result is similar to that of the above exit model. They show that the larger plant reduces capacity first and continues to do so until it shrinks to the size of its smaller rival. Alternatively, the simple size-driven rule can be applied to a continuous divestment problem in an oligopoly. The intuition underlying this result is that the larger plant has lower marginal revenue and hence a greater incentive to cut capacity.\textsuperscript{5}

Second, Whinston (1988) extended the model by considering the plant shutdown decision problem in the presence of multi-plant firms. He showed that in his multi-plant settings the largest plant is not necessarily divested first and a simple rule like the size-based rule of G&N (1985) does not apply. For example, consider a simple situation where two firms are present, Firm A with two plants and Firm B with only one plant. Both of Firm A’s plants are individually smaller than Firm B’s plant, but the sum of the size of Firm A’s plants is greater than Firm B’s plant. Then it is possible that the larger Firm A scraps one of its plants first while Firm B with the largest plant exits second unless Firm A’s efficiency is high enough to maintain both plants for a longer period. This result forms a clear contrast to that of the situation where all three plants are independently held by different firms.\textsuperscript{6}

To the best of our knowledge, there are only a few empirical studies testing the theoretical predictions or examining the divestment behavior in declining industries. One of these is the study by Baden-Fuller (1989), who examines the steel casting

\textsuperscript{4}The larger plant’s monopoly is efficient in two regards: first, it can produce more and, second, its unit cost is lower. Therefore, the per-period welfare in the monopoly of the larger plant is higher than that in the monopoly of the smaller plant.

\textsuperscript{5}This model is also easily extended to a situation with more than two plants.

\textsuperscript{6}The opposite result that Firm B shuts down its plant is also possible. Which outcome arises will depend on a number of aspects of industry structure.
industry in the United States and finds that diversified firms are more likely to shut
down plants. Another is that by Lieberman (1990), who uses data on 30 chemical
products to examine the divestment in declining industries and demonstrates that the
multi-plant firms, which tend to be larger firms, are more likely to cut capacity. Next,
Deily (1991), examining plant closure decisions in the U.S. steel industry, shows the
importance of individual plant characteristics, e.g., size and cost efficiency, for plant
withdrawal decisions. Similarly, Gibson and Harris (1996), focusing on plant exit
during a period of trade liberalization, find the result that efficient plants are more
likely to survive. On the other hand, multi-plant firms are more likely to close plants.
Finally, in a more recent study, Bernard and Jensen (2007) examine the impact of
firm structure on plant closure and find that plants belonging to multi-plant firms and
those owned by multinational firms are less likely to exit.

III  The Cement Industry

This section provides a brief overview of important features of Japan’s cement industry,
including industry trends, the cement production process, and the organization of
cement distribution.

III.1  Trends in Japan’s Cement Industry

The Japanese cement industry provides a good case study for examining divestment
decisions in a period of industry decline. Figure 1 depicts the trends in cement con-
sumption and government and private investment in construction. Cement is the key
ingredient for concrete, which is used as construction material for skyscrapers, road-
ways, railways, airports, seaports, and other infrastructure. Cement consumption thus
mainly depends on construction investment in the private and public sectors, as can
be seen in Figure 1. Cement consumption in Japan increased from the mid-1960s and
expanded until the burst of the bubble economy. Since then, along with the fall in construction investment, cement consumption has been declining and in 2010 stood at less than 50% of its peak in 1991 and at the same level as 40 years ago.

As demand shrank, cement firms had to contract output capacity in order to survive. The reduction in output and capacity is depicted in Figure 2, which shows that about 30% of total capacity was scrapped between 1990 and 2010. The capacity reduction was achieved mainly through a reduction in the number of plants and cement kilns. The number of plants fell from 41 in 1990 to 32 in 2010. In addition, the number of cement kilns, one of the most important facilities in the cement production process, declined substantially, falling from 81 in 1990 to 56 in 2010, as can be seen in Table 1.\(^7\)

Cement plants tend to be located where there are abundant reserves of limestone. This means that in Japan, the Chugoku, Hokkaido, and Kyushu areas account for an overwhelming proportion of cement production, while the major cement consuming areas are the Kanto, Kinki, and Tokai regions. Table 2 provides a list of cement firms in Japan, including their share in national production and the number of plants they had in that year. As can be seen from the table, following a wave of mergers in the period from 1994 to 1998, there are three major firms with more than seven plants: Taiheiyo, Ube Mitsubishi, and Sumitomo-Osaka. These three firms accounted for about 80% of production in 1998 and owned 29 out of total 39 plants in 1998.

The presence of such multi-plant firms is an important characteristic of this industry, meaning that the actual industry structure differs significantly from that considered in the original work of G&N (1985, 1990). Plants even within a multi-plant firm are heterogeneous in size and may also differ in terms of their efficiency. Such heterogeneity may give rise to divestment patterns beyond those predicted by the simple model by Whinston (1988). Given these factors, the actual divestment behavior

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\(^7\)The number of kilns includes inactive kilns.
is likely to be far more complicated than the behavior described in the theoretical
models.

III.2 Cement Production

Cement production consists of the following three processes: (1) the pulverization of
raw materials in order to mix various types of limestone; (2) the firing of the pulverized
materials, which produces cement clinkers; and (3) the pulverization of cement clinkers.

Limestone, the raw material for cement, is transported by ship, land or both to
a dock in a plant. The limestone is then pulverized in order to mix various types
of raw materials, e.g., clay, iron oxide, and gypsum. Mills pulverizing limestone are
called “raw material mills” and represent one of the three main facilities used in the
cement production process. After the pulverized raw materials are mixed together,
they are fired in a rotary kiln to produce cement clinkers. Such kilns play a key role in
the cement production process and substantially determines the production capacity
of a plant. Finally, cement clinkers are pulverized in another type of mill, called a
“finishing mill,” and the finished cement is stored in a silo at the plant or transported
to silos at cement distribution centers throughout Japan.

The amount of cement clinkers produced at a plant is usually used to indicate
the production output of the plant. Similarly, plant capacity is defined in terms of
the annual production capacity of cement clinkers. We follow this convention in this
paper.

III.3 Cement Distribution and the Cement Market

Once produced, the cement is typically delivered by ship from cement plants to cement
distribution centers (called “service stations”) scattered across Japan. In an individ-
ual region, cement firms deliver their products by track from service stations to local
customers, most of which are concrete firms. Transportation from plants to service sta-
tions is called “primary-stage delivery,” while that from service stations to customers (or construction sites) is referred to as “secondary-stage delivery.” Transportation costs related to “primary-stage delivery” play a key role in this study, because they are an important determinant of competition among plants in the Japanese cement industry. Let us therefore look at these transportation costs in more detail.

The costs of “primary-stage delivery,” i.e., transportation costs by sea, are relatively low, making it viable to deliver cement to service stations far from the place of production.\textsuperscript{8} For example, a plant in Kyushu, the southernmost part of Japan, can ship its output to service stations in Hokkaido, the northernmost prefecture, at relatively little cost. This means that a plant can deliver its product to anywhere in Japan if it has a service station there.

To illustrate that primary stage transportation costs play a negligible role, Table 3 shows the distribution of supply quantities by region of two representative plants. Although the data in this table are more than 20 years old, they demonstrate the pattern very well.\textsuperscript{9} Specifically, the table presents the distribution of supply quantities of two plants of Ube Cement Corporation, showing the percentage share of each region in the plant’s total supply as well as the distance of that region from the plant.\textsuperscript{10}

Starting with the plant located in the Chugoku region, the figures show that Chugoku itself accounted for only 14% of total sales, while 24% of the cement produced at the plant was delivered to the Kanto region, which comprises Tokyo and is over 500 miles away. Further, about 9% of the total output was shipped to areas over 700 miles away. The pattern is similar for the Kanda plant located in Kyushu and about

\textsuperscript{8}On the other hand, transportation costs by truck from service stations to customers is very high. These high secondary-stage delivery costs prevent firms from delivering their products to customers far from a service station. This is the reason why cement firms typically set up several service stations within a particular region. Thus, while plants compete nationwide, competition among service stations is confined to a particular region. This element, that is, competition among service stations at the regional level, is another important feature in the Japanese cement industry. However, we do not pursue this aspect here and focus on competition among plants.

\textsuperscript{9}In fact, the pattern showed in the table predates the introduction of larger cement tankers in the early 1990s, which are likely to have reduced primary stage transportation costs even more.

\textsuperscript{10}One region, Okinawa, is excluded from this table because it is an extremely small market.
half the size of the Ube plant, with 80% of its total output shipped to other regions.

The table thus shows that transportation costs by sea are sufficiently low to enable firms to deliver cement to regions far away from production sites, so that it is reasonable to assume that cement plants in Japan compete nationwide. For instance, if, as the two plants in the table, all plants in Japan are able to ship cement to regions 700 miles away, the regions to which plants can deliver cement overlap completely. Even if plants’ delivery distances were shorter than those in Table 3, there would still be a significant overlap in regions to which plants can deliver cement.\textsuperscript{11} Thus, it appears reasonable to treat the Japanese cement market as one market when investigating competition among cement producing plants.\textsuperscript{12}

IV Data

Given that the aim of this study is to examine the impact of firm and plant characteristics on divestment decisions and the potential misallocation of production as a result of such divestments, we focus on the period of decline in the cement industry from 1998-2010. The data we use here are taken from the \textit{Cement Yearbook (Cement}

\footnote{\textsuperscript{11}Plants located inland may have a transportation cost disadvantage over plants in coastal areas, because they have to use railways to deliver cement to the nearest port. The use of railways results in additional transportation costs and the distances that these plants deliver their output may consequently be shorter than those of plants in coastal areas.}

\footnote{\textsuperscript{12}Japanese cement firms export around 12% of their total output. However, although exports are not trivial, we believe that the role of foreign demand in determining industry dynamics is insignificant. The reasons are as follow. First, in general, cement firms do not actively seek to export their products. Rather, cement firms typically aim to maintain a high utilization rate of their plants and for this reason production usually exceeds domestic demand. However, if they were to supply such excess production to the domestic market, this would depress cement price, so to avoid this, firms export any excess output to other Asian countries such as Korea, Taiwan, and Singapore. Thus, it could be said that exports are a by-product of domestic market forces and do not shape them. Second, although there are some exports of cement output, the volume of such exports has not increased despite the rapid economic growth in Asia. Specifically, although Asia has experienced rapid growth over the past two decades, exports to the region peaked the early 1990s. The main reason is that cement production in Asian countries expanded as their economies grew. A typical example is China, where cement production has increased 7 fold over the past 20 years, while imports from Japan have fallen. This provides further indication that exports by cement firms in Japan are driven not by foreign demand but reflect the reason mentioned above.}
Nen-kan in Japanese). The Cement Yearbook is published by the Cement Shimbun Co., Ltd., and provides plant level information on, e.g., the number of kilns, the size of individual kilns, the size of raw and finishing mills, the number of workers, production capacity, production output, and the location and name of the owner (cement firm). We also use the Asian Development Bank Statistical Database System (SDBS) for collecting the information on construction sector GDP of Asian countries.

In the following analysis, we treat both plant exit and a reduction in the number of kilns as capacity divestment. The choice set of a plant manager in reducing production capacity is determined by the number of kilns at his plant and further is not continuous because a kiln is inherently indivisible. Therefore, this decision problem cannot be regarded as a continuous choice problem. Consequently, it is natural to consider that capacity removal is a discrete process that involves the scrapping of one or several kilns and plant exit, and this is the definition we use for divestment.

In the next section we will conduct two regression analyses. The first one is for the estimation of production functions, while the second is the estimation of a probabilistic model of divestment behavior. Summary statistics of the data used for estimating production functions are provided in the first to third rows in Table 4. “Production” is the amount of cement clinkers produced in a plant in terms of million tons. “Labor” is the number of workers in a plant, and “Capital” is the sum of the size of cement kilns and that of raw mills in terms of tons per hour. Finishing mills are excluded from capital input because they are not used in the process of producing cement clinkers and just pulverize the fired clinkers.

Summary statistics of the data for estimating divestment probability are provided in the fourth to last rows in the table. Both “Capacity reduction” and “Exit” are

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13 For example, the largest plant, Karita plant of Ube-Mitsubishi Cement Corporation, has 8 kilns with a production capacity of 255, 221, 156, 155, 146, 112, 81 and 55 tons per hour. Hence, even the plant manager of the largest plant has only a very limited choice set.

14 Ryukyu Cement is excluded from our data set because it operates only in one region, Okinawa, and its production share is very small.
discrete variables, with the former indicating whether a plant reduced the number of kilns and the latter indicating whether a plant exited. “Plant size” refers to plants’ production capacity in terms of million tons. Plant capacity is an estimate by the Japan Cement Association and is defined as the amount that a plant produces in a single year if it operates 600 hours per month. “Inland” is a dummy variable indicating whether a plant is located in an inland area, while “Multi-plant” indicates whether a plant is part of a multi-plant cement firms. “Export demand” is the construction sector GDP of Australia, China, South Korea, Hong Kong, Malaysia, Thailand, and Singapore (in trillion yen).

V Estimation

In this section we examine the effect of firm and plant characteristics on divestment decisions. However, a major obstacle to implementing the empirical test is that plants’ efficiency - one of the most important characteristics of a plant - is unobservable to empiricists. Moreover, we have no information that we could use to proxy unobservable heterogeneity in plant efficiency. This means that we need to estimate plant efficiency. Specifically, we do so by estimating plants’ production function and using our estimate of total factor productivity (TFP) (or multifactor productivity, MFP) as plant specific efficiency.\footnote{A more appropriate approach might be to estimate plants’ cost function; however, data that would allow us to do so unfortunately are unavailable. Van Biesebroeck (2007) compares the robustness of some techniques widely used for estimating productivity.}

We first follow a traditional parametric approach assuming a Cobb-Douglas production function to estimate plants’ efficiency. Such a parametric approach provides us with benchmark estimates for plants’ efficiency. In addition to this, we employ a nonparametric approach in estimating the production functions. Such a flexible approach is advantageous because we have no prior knowledge on the shape of the
production function of cement producing plants.\footnote{An excellent survey of recent advances in non-/semi-parametric techniques and their application in various fields of applied microeconomics is provided by Ichimura and Todd (2008).} Using these estimates, we then proceed to examine how observed and unobserved plant characteristics affect capacity removal decisions.

V.1 Plant Efficiency

We begin by estimating the plant-level production functions and regard the TFP we obtain as a proxy variable for efficiency. The estimated productivity can then be used in the subsequent analysis to test how plants’ characteristics affect capacity withdrawal behavior. Although plants’ productivity is a key variable in this study, estimating the plant-level production functions and plants’ efficiency is not a straightforward task due to the following two reasons. The first is the well-known issue of endogeneity with regard to observed inputs, capital and labor. The endogeneity problem arises from the fact that empiricists cannot observe all of the determinants of production. Unobserved productivity, which is one of the determinants of production, will often correlate with observed inputs and cause endogeneity problems if plant managers know the productivity of their plant and then determine input levels based on this. In general, to estimate a production function consistently, we have to deal with this endogeneity problem stemming from unobserved productivity.

The second reason, although surprisingly it has been noted much less frequently in the literature, is the restriction on the shape of the production function. In almost all cases, when estimating production functions, researchers impose shape restrictions. However, in general, there are problems inherent in using a specific functional form for inference when the actual functional form is unknown (see White, 1980, and Pagan and Ullah, 1999, for detailed discussions). For example, estimates of the parameters of the production function are not consistent and, as a result, the substitution pattern between inputs is mismeasured. Further, even if we resolve the endogeneity issue under
the assumption of a particular functional form, e.g., a Cobb-Douglas, the estimates might still be biased because of misspecification.

With these issues in mind, we take two alternative approaches. The first one is a traditional approach where we use a Cobb-Douglas specification and focus on the endogeneity issue. Here, we use a traditional fixed effects model with instrumental variables to deal with the potential endogeneity problem arising from the plant manager’s input decision. This gives us some benchmarks for plants’ efficiency.

The second one is a flexible nonparametric approach where we deal with the second issue rigorously. Because we have no prior knowledge about the shape of the production function of cement producing plants, we cannot impose a particular functional form on the production function in advance. We therefore consider a flexible production function while putting a restrictive assumption on unobserved efficiency. That is, we treat the production function as a nonparametric production function with Hicks-neutral unobserved productivity. The nonparametric production function corresponds to the infinite order approximation to the unknown production function of cement producing plants. This specification has a clear advantage over other specifications, e.g., a Cobb-Douglas production function, which is the first order approximation to the unknown function, and a translog production function, which is the second order approximation to that function.

The production function of a cement producing plant is defined as

\[ Y_{it} = Y(\Omega_{it}, K_{it}, L_{it}) = \Omega_{it} F(K_{it}, L_{it}) \]  

(1)

where \( \Omega_{it} \) is unobserved heterogeneity of plant \( i \) and is assumed to be Hicks-neutral, \( L_{it} \) is the number of workers in plant \( i \), and \( K_{it} \) is capital, the sum of cement kilns and raw material mills in terms of tons per hour.
Ωₜ represents total factor productivity (TFP) and captures variations in output not explained by \( L_t \) and \( K_t \). One potential driver for productivity differences among plants is the degree of automatization of the production process. In the early 1990s, many, but not all, cement plants introduced computer assisted production management systems, which assist plant workers in operating cement kilns and material and finishing mills.

Raw material mills, which pulverize limestone, for example require many steps to be activated. If a plant has not introduced a computer assisted management system, workers have to carry out all of the necessary steps manually in the appropriate order and at the appropriate speed. If they fail to do so, the mill vibrates excessively, and such vibration may result in the mill having to be stopped frequently, leading to delays in the production process. In addition, excessive vibration is one of the main causes for the breakdown of material mills. Since it takes considerable time to fix a mill, machine breakdowns interrupt the entire production process.

The introduction of information technology (IT) automates these steps, reducing the potential for mistakes by workers in activating mills and kilns, and thus minimizes the interruption of the production process. Consequently, differences in the degree of automatization of the production process across plants will result in differences in productivity. We do not have clear information on the degree of automatization or IT usage at individual plants, so that differences in automatization will be captured by Ωₜ.

Our data set unfortunately lacks information on intermediate inputs for cement production, and Ωₜ contains unobserved intermediate inputs. Therefore, if there are substantial cross-sectional differences in prices for intermediate inputs, our productivity measure will not reflect plants’ true productivity. To illustrate this problem,

\[ \text{A comprehensive survey of recent empirical work addressing the sources of productivity differences is provided by Syverson (2010). TFP typically contains managerial efficiency, intangible assets, and unmeasured input quality.} \]

\[ \text{We are grateful to an anonymous referee for this point.} \]
let us assume that there are two equally efficient plants facing different intermediate input prices, e.g., prices for limestone, fuel, electricity, and water. In this case, the plant facing lower prices will use more intermediate inputs and produce more output. Without information on intermediate inputs, this plant is observationally more productive than the other. In fact, however, it is the difference in input prices that causes differences in output between the two plants. Therefore, due to the lack of information on intermediate inputs, our productivity estimates will be potentially contaminated in this manner. However, prices of key inputs such as fuel, electricity, and water, for instance, do not differ significantly across Japan, and plants are typically located in areas where limestone is abundant, as previously explained, so that transportation costs are not expected to differ much across plants.

We start our estimation of the production function with the following Cobb-Douglas specification (logarithmic form):

\[
y_{it} = \omega_{it} + f(L_{it}, K_{it}) = \beta_{l}l_{it} + \beta_{k}k_{it} + \xi_{i} + \zeta_{t} + \psi_{it} + \epsilon_{it}.
\]  

(2)

where \(\xi_{i}\) is plant-specific unobserved productivity and is assumed to be constant at least during the observation period, \(\zeta_{t}\) is a year-specific productivity shock, \(\psi_{it}\) indicates measurement errors, and \(\epsilon_{it}\) is a (possibly) autoregressive unobserved productivity shock, which is potentially correlated with both inputs. We assume that \(\epsilon_{it}\) follows an AR(1) process with an unexpected productivity shock \(e_{it}\), that is, \(\epsilon_{it} = \rho \epsilon_{it-1} + e_{it}\).

To estimate this production function, we employ three estimation methods. The first is to estimate the production function by ordinary least squares (OLS) with year dummies. The second is to estimate the production function by using a fixed effects model which includes plant dummies for controlling plant specific productivities as well as year dummies (FE). And third, because \(\psi_{it}\) and \(\epsilon_{it}\) are potentially correlated
with inputs, we use lagged values of inputs as instrumental variables and estimate
the production function using the Blundell and Bond (2000)’s generalized method of
moments (GMM) approach. This GMM estimator will solve the potential endogeneity
issue caused by time-varying productivity $\epsilon_{it}$ as well as that by measurement errors
$\psi_{it}$. Details of the GMM estimation procedure are provided in the Appendix.

Table 5 presents the estimation results. The OLS estimates are shown in the first
column, while the fixed effects (FE) estimates and the instrumental variables estimates
(GMM) are in the second and third columns. The OLS estimates are higher than the
estimates using the other two approaches. Since unobserved productivity positively
correlates with output and both inputs, the OLS estimates will have positive bias. The
FE estimator eliminates the part of this bias by introducing the time-invariant plant
specific productivities, while the GMM solves this endogeneity problem by allowing
the time-varying unobserved productivities and measurement errors as well as the
time-invariant productivities to be correlated with inputs.\footnote{The FE and GMM estimates seem to exhibit decreasing returns to scale. But, our regression models lack intermediate inputs. The effect of these unobserved variables will be captured partly by plant and year dummies. Therefore, we cannot decide whether the cement producing plants in Japan exhibit decreasing returns to scale.}

We now turn to the flexible approach to estimating cement plants’ production func-
tion. The nonparametric production function is defined in the following logarithmic
form:

$$y_{it} = \omega_{it} + f(L_{it}, K_{it}) = f(L_{it}, K_{it}) + \xi_i + \zeta_t + \psi_{it} + \epsilon_{it}$$  \hspace{1cm} (3)$$

where, as before, $\xi_i$ is plant-specific unobserved productivity and is assumed to be
constant at least during the observation period, $\zeta_t$ represents industry-wide year effects,
$\psi_{it}$ is measurement errors, and $\epsilon_{it}$ is a time-varying productivity shock following an
AR(1) process.\textsuperscript{20} This is a very flexible production function - except for the assumption that unobserved productivity, $\omega_{it}$, is Hicks-neutral - since no shape restrictions on the form of $f(\cdot)$ and the relation between both inputs are placed.\textsuperscript{21}

The production function represented by (3) is a partial linear regression model. We estimate the unobserved effects, $\xi_i$ and $\zeta_t$, and the unknown function $f(K_{it}, L_{it})$ using the following two steps.\textsuperscript{22} First, we use the double residual method of Robinson (1988) to obtain estimates of the firm-specific productivity $\hat{\xi}_i$ and the time effect $\hat{\zeta}_t$. Second, we then regress adjusted production quantities $\tilde{y}_{it} = y_{it} - \hat{\xi}_i - \hat{\zeta}_t$ on $K_{it}$ and $L_{it}$ nonparametrically to estimate the shape of the production function. In both steps we use a local linear estimator for the conditional mean functions using a univariate normal kernel and set the bandwidths employing Silverman’s rule of thumb. The shape of the production function is presented in Figure 3. We also estimate $\rho$, and its estimated value is 0.5030 with a standard error of 0.0500.

Using the production functions estimated employing the different specifications and different estimation procedures, we calculate plant efficiency estimates as follows:

$$\hat{\Omega}_{it} = \exp(y_{it} - \hat{f}(K_{it}, L_{it})), \quad (4)$$

where $\hat{f}$ is the production function estimated by employing one of the four approaches described above. Table 6 shows the correlation and rank correlation between the four different efficiency estimates. At least with regard to the productivity estimates, we find that there are no substantial differences among the different specifications, with

\textsuperscript{20}In contrast with the specification of the Cobb-Douglas production function above, $\epsilon_{it}$ and $\psi_{it}$ are now assumed not to correlate with any inputs. We thus make stricter assumptions on the error terms.

\textsuperscript{21}This could be considered to be a non-additive separable production function. However, in order to identify the function $Y(\cdot)$ and the distribution of $\Omega$, $F_\Omega$, we need other restrictions on the form of the production function or the substitution pattern among inputs (see Matzkin, 2003, and Altonji and Matzkin, 2005).

\textsuperscript{22}This estimation procedure corresponds to the profile likelihood (least squares) method of Su and Ullah (2006).
the exception of the Cobb-Douglas OLS. The similarity between the Cobb-Douglas FE estimates and the nonparametric FE estimates suggests that the Cobb-Douglas specification is a good approximation of the unknown production function of cement producing plants. The similarity between the GMM and FE estimates suggests that the correlation between inputs and time-variant plant specific productivity does not cause a serious problem, at least in estimating plant productivity. However, in the subsequent regression and experimental analyses, we will use all four different productivity measures in order to check the robustness of our results.

V.2 Capacity Divestment Behavior

This subsection examines the impact of plant and firm characteristics on capacity reduction and plant exit behavior. For this purpose, we prepare two sets of empirical specifications. In the first set of specifications, we simply test the relationship between plant characteristics and divestment behavior. Doing so, one of the issues we focus on is the effect of whether a plant is part of a multi-plant firm, which is likely to be an important determinant, on divestment behavior. In the second set of specifications, taking into account that plants are owned by firms and that it is firms and not individual plants that make the divestment decision, we analyze divestment behavior with particular emphasis on the role of intra-firm differences of plant characteristics as well as inter-firm differences of firm characteristics.\(^{23}\) Therefore, the second set of specifications can be thought to explore the driving forces of capacity divestment in greater detail, while the first provides us with a descriptive analysis.

In the first set of empirical specifications, we prepare the following explanatory variables. Relative size is the size of a plant relative to the mean of all plants within the industry and relative efficiency is the efficiency of a plant relative to the mean of all plants in the industry as well. For the calculation of relative efficiency, we utilize

\(^{23}\)In the case of singleplant firms this of course means that only differences in firm characteristics matter.
plants’ TFP level estimated by using one of the four approaches explained in the previous subsection. Because plants located inland may have a transportation cost disadvantage relative to plants in coastal areas, and, as a result, may be more likely to reduce their capacity and exit, a dummy variable indicating whether a plant is located inland or on the coast is introduced. In addition to these plant characteristics, we control for the potential effect of exports on divestment, using export demand calculated as the construction sector GDP of Australia, China, South Korea, Hong Kong, Malaysia, Taiwan, Thailand, and Singapore (in trillion yen) as an additional variable.

In the second set of specifications, we turn to the main focus of this paper and examine the effects of intra- and inter-firm characteristics on the probabilities of capacity reduction and exit simultaneously. For this purpose, suitable explanatory variables need to be chosen. Previous theoretical work helps us to construct covariates and provides some testable hypotheses: (1) Firm size (or plant size) is a key determinant of divestment behavior (G&N 1985, 1990); (2) firm efficiency (or plant efficiency) does not have an effect on divestment behavior unless the firm (or plant) has a large efficiency advantage over its smaller rivals (G&N 1985); (3) the divestment behavior of a plant owned by a multi-plant firm is influenced by firm size (Whinston 1988); and (4) the divestment behavior of a plant owned by a multi-plant firm is influenced by the firm’s efficiency (Whinston 1988).

In addition to these predictions from theoretical models, we pay careful attention to the effect of intra-firm heterogeneity on the divestment behavior of a plant. The reason is that during the period we focus on, several large firms with multi-plant firms emerged as a result of mergers. Their behavior plays an important role in the welfare implications of the pattern of capacity reduction in the industry as a whole, because cement firms with several plants are in a position to choose from among a number of plants when forced to reduce capacity, and we would therefore expect them to pick less
efficient plants to do so. Whether this is indeed what happened is one of the things we examine.\(^{24}\)

Whether so-called “capacity rationalization,” in which the capacity of inefficient plants is reduced or such plants are shut down, can be observed is of particular importance in competition policy on mergers in declining industries. In declining industries, mergers that result in capacity rationalization, with inefficient plants being shut down and production begin shifted to more efficient plants, can increase economic welfare (Dutz 1989), providing a rationale for mergers. Of course, in order to evaluate whether economic welfare does indeed increase, we would need to know whether the inefficiency gain through mergers is greater than the loss of the consumer surplus. While the necessary information for this kind of comparison is unfortunately unavailable, our analysis allows us to examine at least part of the equation, i.e., whether capacity reduction behavior within multi-plant firms is efficient.

Based on the theoretical predictions and our interest in the effect of plant heterogeneity within multi-plant firms on the probability of divestment, we construct the following variables; Relative firm size; relative firm efficiency; relative plant size; and relative plant efficiency.

Relative firm size indicates the relative size of the firm owning plant \(i\) and is used to examine whether capacity reductions are determined by firm size. The variable is defined as the difference from the mean of firm-level production capacity within the industry at each specific point in time, where firm-level production capacity is calculated simply as the sum of the capacity of all plants owned by a particular firm. Another variable we employ is relative plant size, which is the size of a plant relative to the mean of all plants within the same firm. This variable is constructed based on production capacity and examines whether plant size is a determinant of capacity

\(^{24}\)In their study on the telecommunications equipment industry, Olley and Pakes (1996) point out that there was significant inefficiency in the allocation of output across plants in the industry once market structure moved away from monopoly.
reductions within a firm. This variable is zero for single-plant firms, since a plant in a single-plant firm cannot be influenced by other plants within the firm.

Relative firm efficiency is the relative efficiency of the firm owning plant $i$ and is measured as the difference from the mean of the efficiency level of all firms. The efficiency level of an individual firm is calculated as the mean of the efficiency level of all plants owned by the firm at each specific point in time. This variable examines whether differences in firm-level efficiency affect capacity reductions. Finally, relative plant efficiency is the efficiency of a plant relative to the mean of all plants within a firm. If a firm faces pressure to reduce production capacity, we would expect it to pick a less efficient plant among its own plants. This value is zero for a single-plant firm.

We estimate divestment probabilities using a ordered probit model and show the marginal effects of the above mentioned variables on capacity reduction and exit. In calculating the standard errors, we should account for the first stage-estimation error (the estimation error in plant efficiency) and serially correlated unobservables. To deal with these issues, we calculate the standard errors by block bootstrapping.\footnote{We randomly draw 500 samples of 38 complete plant histories with replacement.}

\section{VI Estimation Results}

This section presents our empirical results. Tables 7 and 8 show the results of the ordered probit models. We start with Table 7, which shows the marginal effects of plant characteristics on the probabilities of capacity reduction and exit for the various efficiency measures.

The coefficient on relative size is statistically significant at the 5\% level for three out of the four different efficiency measures. When we use the efficiencies estimated using the flexible production function, the marginal effects of plant size on the probabilities of capacity reduction and plant exit are around 0.0301 and 0.0185, respectively. These coefficients mean that an increase in a plant’s size by one standard deviation (1.6163)
is associated with an increase of about 4.8-percentage points in the probability of capacity reduction and an increase of about 3.0-percentage points in the probability of exit. Put differently, a one standard deviation increase in plant size increases the probability of divestment by about 7.8-percentage points. Taking into account that the unconditional divestment rate during the period is 5.4%, the magnitude of the increase is substantial. These estimates thus reveal that larger plants are more likely to reduce the number of kilns and to exit.

The effect of relative efficiency is also statistically significant at the 5% level for all efficiency measures. Again, when we use the efficiencies estimated using the flexible production function, the marginal effects of plant efficiency on the probabilities of capacity reduction and plant exit are around -0.1903 and -0.1167, respectively. These coefficients mean that an increase in a plant’s efficiency by one standard deviation (0.2465) is associated with a decrease of about 4.6-percentage points in the probability of capacity reduction and a decrease of about 2.9-percentage points in the probability of exit. In other words, moving one standard deviation up in plant efficiency lowers the divestment probability by about 7.5-percentage points.\(^{26}\)

These results on plants’ size and efficiency show that larger and less efficient plants are more likely to divest. This finding provides partial support for G&N’s (1985, 1990) hypothesis suggesting that larger plants reduce their capacity, although so far we have not explicitly included the effect of any interactions among firms.

The other variables have the expected signs but they are not statistically significant. The coefficient on the location dummy for plants located inland is positive, as expected, although it is not statistically significant.\(^{27}\) The marginal effect of construction demand in foreign countries is also statistically insignificant, and its economic magnitude on

\(^{26}\)This result on the effect of plant efficiency on exit is consistent with previous empirical findings such as those by Olley and Pakes (1996), Hortaçsu and Syverson (2007), and Foster, Haltiwanger, and Syverson (2008), who find that more efficient plants are more likely to survive.

\(^{27}\)The marginal effects may be substantial because the 95% confidence intervals for the marginal effects on capacity reduction and exit are about \((-0.0178, 0.0566)\) and \((-0.0198, 0.0456)\), respectively.
divestment probabilities is also small. A one standard deviation increase (4.7516) in export demand lowers the probability of divestment by less than 1-percentage point. Even if we consider the entire 95% confidence interval for the marginal effect, the magnitudes are still economically insignificant. This finding supports the view that export demand is not an important determinant of divestment in Japan’s cement industry.

Next, we examine whether the divestment behavior of plants that are part of a multi-plant firm differs from that of single-plant firms by adding the multi-plant dummy to our analysis. The results are shown in the third and fourth columns for each productivity measure and indicate that the coefficient on the multi-plant dummy is positive. While for all of the productivity measures the marginal effect is not statistically significant at the 5% level, we take a careful look at the confidence intervals to investigate whether they can potentially tell us something about the economic magnitude of the marginal effects. When we use the flexible production function, the 95% confidence interval for the marginal effect of the multi-plant dummy on the capacity reduction probability and that on the exit probability are (−0.0076, 0.0316) and (−0.0086, 0.0228), respectively. These confidence intervals mean that multi-plant status does not seem to have a substantial negative impact on the divestment probabilities because the lower bounds of the marginal effects are both less than 1-percentage point (in absolute value). Plants that are part of a multi-plant firm are not more likely to maintain capacity.

We now turn to Table 8, where we simultaneously take account of the strategic position of a plant and that of the firm owning the plant. Here, we take a close look at what intra-firm differences in plant characteristics as well as inter-firm differences in firm characteristics determine whether a plant reduces capacity. We first include only the firm-level characteristics. The marginal effects of relative firm size are not statistically significant at the 5% level for all of the four efficiency measures, although
they have a reasonable sign. Because relative firm size is an important variable, we carefully look at the confidence intervals for the coefficients and investigate the economic magnitudes of the null hypotheses that we cannot reject. For example, the 95% confidence interval for the marginal effect of relative firm size on the capacity reduction probability and that for the effect on the exit probability are about (-0.0006, 0.0025) and (-0.0005, 0.0019), respectively, when using estimates in (4). This means that given the standard deviation of relative firm size (10.1677) these marginal effects are likely to be small.

The coefficient on relative firm efficiency is negative except the value in specification (3), as expected. However, it is not significant at the 5% level for all of the efficiency measures. Again, we construct the 95% confidence interval for the marginal effect on the capacity reduction probability and that for the effect on the exit probability. When using estimates in (4), the 95% confidence interval for the marginal effect of relative firm efficiency on the probability of capacity reduction is (-0.0932, 0.0930) while that for the marginal effect on the exit probability is (-0.0763, 0.0762). Taking account of that one standard deviation in relative firm efficiency is 0.1645, the marginal effect of relative firm efficiency appears to be small like that of relative firm size.

Next, we introduce plant-level variables to investigate the effect of intra-firm differences in plant-level characteristics as well as that of inter-firm differences in firm-level characteristics on divestment probabilities. Relative plant size (intra-firm difference in plant size) is significant at the 5% level for all productivity measures. When we use the flexible production function, an increase in relative plant size of one standard deviation (1.4026) increases the probabilities of capacity reduction and exit by about 4.2- and 2.5-percentage points, respectively. That is, a one standard deviation change in within-firm size changes the probability of divestment by about 6.7-percentage points. This magnitude of the effect of relative plant size is not only statistically significant but also economically significant, given that the unconditional divestment rate is 5.4%.
Relative plant efficiency (intra-firm difference in plant efficiency) is also statistically and economically significant and its marginal effects are similar to those of relative plant size. A one standard deviation increase in this variable (0.2465) is associated with a 4.5-percentage point decrease in the capacity divestment rate and a 2.7-percentage point decrease in the exit rate, when we employ the efficiency estimates obtained from the nonparametric production function. In total, the probability of a plant taking any action decreases by 7.2-percentage points. Conversely, this result reveals that less efficient plants within a multi-plant firm are more likely to reduce their capacity and exit.

Even after controlling within-firm differences in plant size and efficiency, the marginal effects of the relative firm variables on capacity reduction and on exit are still not statistically significant at the 5% level. The marginal effects of relative firm size are not statistically significant, and its economic magnitudes are essentially the same as before. For example, when using the nonparametric production function, the 95% confidence interval for the marginal effect of relative firm size on the capacity reduction probability and that for the effect on the exit probability are about (-0.0009, 0.0018) and (-0.0008, 0.0012), respectively. Taking account of the standard deviation of relative firm size (10.1677), these marginal effects are relatively small in comparison with those of relative plant size.

The coefficients on relative firm efficiency are not statistically significant as before, while they dramatically get larger than before. Again, we construct the 95% confidence interval for the marginal effect on the capacity reduction probability and that for the effect on the exit probability. The 95% confidence interval for the marginal effect of relative firm efficiency on the probability of capacity reduction is (-0.1830, 0.0146) while that for the marginal effect on the exit probability is (-0.1255, 0.0223) when using the nonparametric production function. Given that one standard deviation in relative firm efficiency is 0.1645, relative firm efficiency appears to have no substantial
positive effect on the divestment probability. On the other hand, we cannot reject the possibility that relative firm efficiency has a substantial negative effect: the lower bounds of the marginal effect imply that a one standard deviation increase in relative firm efficiency reduces the probabilities of reducing capacity and exit by 3.0- and 2.1-percentage points, respectively. However, these values at the lower bounds are relatively small in comparison with the effects of the within-firm efficiency while the confidence intervals include non-trivial values.

The results of our main empirical analysis can be summarized as follows. We find that the effects of differences in firm size and efficiency are not statistically significant and not substantial in size. On the other hand, differences in plant efficiency and in plant size do have an influence on the divestment probability. What these results suggest is that when firms are under pressure to divest, and they have several plants under their control, they pick less efficient plants in their choice set to reduce capacity. To this extent, multi-plant firms contribute to the efficient industry contraction. However, our results also suggest that less efficient firms do not necessarily reduce production capacity more than efficient firms. Such inefficient divestment pattern may lead to a loss in welfare.

In the next section, to supplement the regression analysis, we examine what these observed divestment patterns mean in terms of production allocation efficiency. In particular, we investigate whether the wrong firms produce more than they should and quantify the extent of allocative inefficiency.

**VII Production Reallocation**

In the previous section, we investigated how plant and firm characteristics affect the probability of capacity divestment. However, the regression analysis there yielded ambiguous results regarding the overall divestment behavior and does not say anything about the reallocation of production resulting from these capacity removals. To
supplement the previous analysis, we conduct an experimental analysis to measure how the divestments affect the efficiency of production allocation in the industry as a whole. By comparing the realized production allocation with a desirable outcome, the analysis seeks to quantify how close the actual allocation of production comes to the optimal allocation.

We consider the following production allocation as the optimal solution to the allocation problem in the industry. Assume there is a social planner allocating production across plants in each year from 1998 to 2010. Further, assume that the planner can have access to all plants, which were actually active in 1998, and that the planner can use the same level of production capacity that these plants had in 1998. Given the total amount of production in each year, the planner chooses plants according to their efficiency and allocates production quantities to them up to their capacity. This allocation of output quantities can be considered to be the most efficient allocation given the total amount of output volume. We then compare the optimal production allocation thus obtained with the actual allocation of production.

To measure the allocation efficiency, we construct the following index:

\[ C_t = \sum_{i=1}^{N} \frac{Y_{it}}{\hat{\Omega}_{it}} \]  

(5)

where \( Y_{it} \) is plant \( i \)'s production quantity in year \( t \), which is the quantity allocated by the planner or just the observed quantity of plant \( i \), and \( \hat{\Omega}_{it} \) is plant \( i \)'s estimated productivity in year \( t \). The meaning of this allocation index is straightforward. Given

28In this experiment we eliminate the possibility that plants expand their capacity. For example, we rule out the behavior that a firm shuts down all of its plants except the most efficient plant and expands the capacity of that plant.

29The sequence of a plant’s productivity \( \{\hat{\Omega}_{it+1}, \hat{\Omega}_{it+2}, \ldots, \hat{\Omega}_{t(2010)}\} \) cannot be calculated if the plant exited in year \( t \). In this case, we extrapolate the sequence following the year of exit using the autoregressive coefficient estimate \( \hat{\rho} \) and the random draw, \( e_{it} \), in the following way:

\[ \hat{\Omega}_{it+1} = \exp(\hat{\xi}_t + \hat{\xi}_{t+1} + \hat{\rho}e_{it} + e_{it+1}) \]  

(6)

where \( e_{it+1} \) is the random draw, which is assumed to follow a normal distribution in this experiment.
the total amount of production, the index is lower the more of the total production is produced by more efficient plants. Therefore, the allocation that achieves the lowest value of this index is the optimal production allocation.

The social planner’s allocation, the first best allocation, is the solution to the following minimization problem:

$$\min_{Y_{1t}, \ldots, Y_{Nt}} C_t$$

s.t. $\sum_{i=1}^{N} Y_{it} = \bar{Y}_t$

$$Y_{1t} \leq CAP_1$$

$$\vdots$$

$$Y_{Nt} \leq CAP_N$$

where $\bar{Y}_t$ is the (observed) total production quantity in year $t$ and $CAP_i$ is plant $i$’s capacity level in 1998. We call the solution of this planner’s allocation problem the first-best allocation, $C_{t}^{1st}$.

We calculate the ratio of the allocation index of the first-best allocation to that of the actual allocation and define this as the total allocative efficiency index:

$$R_t = \frac{C_{t}^{1st}}{C_t^a}$$

where $C_{t}^{a}$ is the actual allocation index in year $t$, which is calculated by inserting observed quantities and efficiencies into (5). This ratio measures how efficient the observed allocation is relative to the best allocation.

Table 9 shows the results of this experimental exercise. The columns named “Total” display the total allocative efficiency defined in (8) above. It should be noted that what matters is not the level of this ratio, but its trend over time. Although the size of the ratio varies depending on which productivity measure is used, we find that in all
cases allocative efficiency falls substantially. Specifically, the total allocation efficiency declines by about 5-18 percentage points over time as capacity in the industry is reduced and plants exit. For example, in the specification with the nonparametric production function, the industry achieves 88.1% of the first-best allocation in 1998. The ratio falls gradually and reaches around 74.6% in 2010 as capacity divestment takes place. Thus, the experimental exercise suggests that capacity reductions resulted in a 13.5-percentage point drop in total allocative efficiency, because less efficient firms or plants produced more than the social planner would want them to produce (the exercises using other efficiency measures produce similar results).

The ratio itself is very informative. However, we are also interested in the determinants of this efficiency drop and therefore examine it in greater detail employing the decomposition proposed by Olley and Pakes (1996). To identify where the inefficiency arises, we decompose the ratio $R_t$ into two terms, an inter-firm and an intra-firm ratio. The efficiency ratio can be rewritten as

$$R_t = \frac{C_{1st}^t}{C_{2nd}^t} = \frac{C_{1st}^t}{C_{2nd}^t} \frac{C_{2nd}^t}{C_{1st}^t}$$  \hspace{1cm} (9)$$

where $C_{2nd}^t$ consists of the sum of each individual firm’s best allocation.\footnote{30} We call this the second-best allocation. The ratio $C_{1st}^t / C_{2nd}^t$, which we call the inter-firm

\footnote{30} is derived as follows. First, we obtain firm $f$’s optimal allocation as the solution to the following minimization problem:

$$\min_{Y_{ft1}, \ldots, Y_{ftP}} C_{ft} \left( \sum_{j=1}^{P} \frac{Y_{fjt}}{\Omega_{fjt}} \right)$$ \hspace{1cm} (10)$$

s.t.  $\sum_{j=1}^{P} Y_{fjt} = Y_{ft}$

$Y_{ft1} \leq CAP_{f1}, \ldots, Y_{fP_t} \leq CAP_{fP}$,

where $P$ is the number of plants owed by firm $f$, $Y_{ft}$ is firm $f$’s (observed) production quantity in year $t$, and $CAP_{fj}$ is plant $j$’s capacity in 1998. Then, we sum each firm’s index, which is derived from the solution of the above problem:

$$C_{2nd}^t = \sum_{f=1}^{FN} C_{f*}$$ \hspace{1cm} (11)$$

where $FN$ is the number of firms and $C_{f*}$ is the best production allocation of firm $f$. 

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allocative efficiency ratio, measures the efficiency loss attributable to inefficiencies in the inter-firm allocation of production. Put differently, this loss can be considered as the efficiency loss arising from the oligopolistic market structure of the cement industry because the difference between the first-best and the second-best allocation is simply whether plants in the industry are operated by one planner or independently by a small number of firms. Next, the second term, $C_{2}^{2nd}/C_{a}$ is the ratio of the allocation index of the second-best allocation to that of the actual allocation. The ratio compares the intra-firm optimal allocation with the actual allocation and we thus call this the intra-firm allocative efficiency ratio.

Examining the inter- and intra-firm ratios tells us where the allocative inefficiency arises. The results of this decomposition for all productivity measures are shown in the columns named “Inter-firm” and “Intra-firm” in Table 9. For example, when using the nonparametric specification of the production function, the total efficiency index, 0.881, in 1998 is decomposed into the inter-firm index, 0.960, and the intra-firm index, 0.918.\(^{31}\) Again, what matters is not the level of this index, but its trend over time. The inter-firm index falls from 0.960 to 0.862 in the 13-year period, while the intra-firm index falls only from 0.918 to 0.865. This decomposition reveals that the largest part of the 13.5-percentage point drop in total allocative efficiency is explained by the drop in inter-firm allocative efficiency (similar results are obtained for the other productivity measures).

This result is reasonable and intuitive, because multi-plant firms were able to be-
have optimally, at least with regard to the choice among their own plants.\textsuperscript{32} This result is also fully consistent with the findings obtained in the estimation of divestment probabilities in the previous section, where it was found that one of the key variables, relative firm efficiency, had no significant effect on divestment and exit probabilities, while intra-firm efficiency, that is, relative plant efficiency, was one of the key determinants of divestment and exit.

The fact that multi-plant firms play an important role in the reallocation of production by shifting production from less efficient plants to more efficient plants suggests that mergers, which the industry experienced in the mid-1990s, can greatly contribute to raising allocative efficiency. The reduced form analysis in the previous section suggested that the reduction of capacity within a firm was conducted on the basis of plants’ efficiency. In other words, the capacity of less efficient plants was more likely to be removed and production consequently shifted to more efficient plants. The experimental exercise in this section suggests that the largest part of the allocative efficiency drop was explained by the inter-firm misallocation of production. This implies that if the mergers had not taken place, the allocative efficiency loss would have been much worse.

However, based only on this result, it is not possible to ascertain that consolidation unambiguously results in an improvement of total welfare: all that can be said is that it has the potential to improve the allocation of production. In our experiment, the production level to be allocated by the planner was set to the actually observed output quantities. However, the output quantity that maximizes the total surplus usually differs from the output quantities actually realized. In many cases, mergers are likely to result in a reduction in total output, leading to a decrease in the consumer surplus and an increase in the producer surplus. Hence, the analysis unfortunately cannot tell

\textsuperscript{32}Consider the extreme case of a monopoly. Clearly, the outcome chosen by the monopolist would be expected to coincide with that of the social planner if the total amount of production is given.
VIII Conclusion

Focusing on the Japanese cement industry, this paper examined divestment behavior in an oligopolistic industry. Specifically, we looked at the inefficiencies potentially arising in an oligopolistic industry, examining the issue from two angles: inefficiency in the choice of firms or plants for reductions in production capacity and the potential misallocation of production arising from such capacity divestment. First, regarding potential inefficiencies arising in the divestment process, we examined whether more efficient plants (firms) were more likely to reduce their production capacity than their less efficient counterparts. Second, we then looked at how close the resulting production allocation came to the optimal allocation of production within the industry.

With regard to capacity reduction and exit, we found that the within firm variables - that is, the relative efficiency and relative size of a plant within a multi-plant firm - were important determinants. Thus, within firms, losers (less efficient plants) are picked. On the other hand, the impact of differences in firm-level variables on the divestment probability was neither statistically significant nor substantial in size. Next, our experimental exercise showed that the divestment pattern actually observed resulted in a substantial drop in total (industrywide) allocative inefficiency during the period from 1998 to 2010. We further investigated the causes of this inefficiency and found that most of the total allocative inefficiency is explained by inter-firm allocative inefficiency.

Our results suggest that the presence of multi-plant firms has likely been beneficial from the viewpoint of total allocation efficiency in the period of decline in the Japanese cement industry.\footnote{A related study examining the welfare implication of mergers in a declining industry is conducted by Nishiwaki (2010). The study discusses the divestment decisions of firms in the Japanese cement industry with a particular emphasis on the role of horizontal mergers in a fully dynamic structural model and concludes that the merger-induced rationalization improved total welfare.}
cement industry. This in turn suggests that mergers may play an important role in capacity consolidation during periods of industry decline.

Finally, an important issue not addressed in this study should be mentioned. That is, while we examined whether efficient plants divested capacity or not, we did not investigate the timing of capacity reduction and exit. However, theoretical studies such as those of G&N (1985) and Whinston (1988) suggest that welfare losses may arise not only as a result of the exit of efficient plants but also as a result of the wrong timing of such exits. That is, efficient plants may exit too early from the viewpoint of total welfare. Put differently, the social planner maximizing total welfare in a declining industry would want such plants to stay longer. Therefore, the worst case scenario in a declining industry is that the wrong plants, that is, more efficient plants, exit, and they do so at the wrong time, that is, too early. To examine whether such a scenario can be observed in real-world industries is a very interesting and important empirical topic from the viewpoint of total welfare. We leave this for future research.

A Estimating the Cobb-Douglas Production Function

To estimate the production function, we use the system generalized method of moments (GMM) estimator by Blundell and Bond (1998). The Blundell and Bond system GMM estimator exploits two sets of moment conditions. The first set of moment conditions consists of first-differenced equations and lagged variables, which serve as instrumental variables, while the second set consists of equations in levels and first-differences of lagged variables serving as instruments. The system GMM estimator using these sets of moment conditions is potentially a less biased estimator than both the standard first-differencing GMM estimator proposed by Arrelano and Bond (1991) using only the first set of moment conditions and the level GMM estimator of Arrelano and Bover
Following Blundell and Bond (2000), we rewrite (2) as follows:

\[ y_{it} = \beta_l l_{it} + \beta_k k_{it} + \xi_i + \zeta_t + \psi_{it} + \epsilon_{it} \]

\[ = \beta_l l_{it} + \beta_k k_{it} + \xi_i + \zeta_t + \psi_{it} + \rho \epsilon_{it-1} + \epsilon_{it} \]

\[ = \beta_l l_{it} + \beta_k k_{it} + \xi_i + \zeta_t + \psi_{it} + \rho (y_{it-1} - \beta_l l_{it-1} - \beta_k k_{it-1} - \xi_i - \zeta_{t-1} - \psi_{it-1}) + \epsilon_{it} \]

\[ = \beta_l l_{it} + \beta_k k_{it} + \rho (y_{it-1} - \beta_l l_{it-1} - \beta_k k_{it-1}) + (1 - \rho) \xi_i + (\zeta_t - \rho \zeta_{t-1}) + \psi_{it} - \rho \psi_{it-1} + \epsilon_{it} \]

\[ = \beta_l l_{it} + \beta_k k_{it} + \rho y_{it-1} - \rho \beta_l l_{it-1} - \rho \beta_k k_{it-1} + (1 - \rho) \xi_i + (\zeta_t - \rho \zeta_{t-1}) + w_{it}. \quad (12) \]

To derive our first set of moment conditions, we eliminate the plant-specific fixed effect \( \xi_i \) in (12) by taking first differences. Then, the resulting unobserved components become

\[ \Delta w_{it} = w_{it} - w_{it-1} = (\psi_{it} - \rho \psi_{it-1} + \epsilon_{it}) - (\psi_{it-1} - \rho \psi_{it-2} + \epsilon_{it-1}). \quad (13) \]

The key for constructing orthogonality conditions is that the above composite error term is uncorrelated with the three-period (and further) lagged values of \( k_{it}, l_{it}, \) and \( y_{it} \), because the measurement error, \( \psi_{it} \), and the unexpected productivity shock, \( \epsilon_{it} \), are serially uncorrelated unobserved components under our assumption.\(^{35}\)

---

\(^{34}\)Hayakawa (2007) explains why the bias of the system GMM estimator is potentially smaller than that of both the first-differencing estimator and the level estimator. He shows that part of the bias of the system GMM estimator is a weighted sum of the bias of the first-differencing estimator and that of the level estimator. The biases of these two estimators are in opposite directions and thus cancel each other out. For this reason, the system GMM estimator exploiting two sets of moment conditions is potentially less biased than each of the two GMM estimators using only one set of moment conditions.

\(^{35}\)However, a possible concern is that this moment condition is invalid because of our lack of information on intermediate inputs. When intermediate inputs are included as unobserved terms, the composite error term will be

\[ (\psi_{it} - \rho \psi_{it-1} + \epsilon_{it} + \beta_m m_{it} - \rho \beta_m m_{it-1}) - (\psi_{it-1} - \rho \psi_{it-2} + \epsilon_{it-1} + \beta_m m_{it-1} - \rho \beta_m m_{it-2}), \]

where \( m_{it} \) is an intermediate input and \( \beta_m \) is its coefficient. The resulting error term will highly
Therefore, the first set of moment conditions for estimating the parameters of the production function (12) are

\[ E[\Delta w_{it} x_{is}] = 0, \]

(14)

where \( x_{is} = (l_{is}, y_{is}) \) and \( s \leq t - 3. \)

In addition to the above set of moment conditions, we use the level equations (12) and lagged differenced variables as instruments to form the second set of moment conditions. Blundell and Bond (1998) show that these additional moment conditions potentially reduce bias caused by weak instruments, which often arise in persistent panel data.\(^\text{37}\) The second set of moment conditions are

\[ E[((1 - \rho) \xi_{i} + w_{it}) \Delta x_{is}] = 0, \]

(15)

where \( x_{is} = (l_{is}, y_{is}) \) and \( s \leq t - 2. \)

We combine these two types of moment conditions to estimate the Cobb-Douglas production function.

References


\( ^{36}\)Here we need to assume that capital input \( k_{it} \) is not correlated with \( w_{it} \). The reason why we treat \( k_{it} \) in such a manner is very practical. \( k_{it} \) does not change very frequently and due to this, when lagged values of \( k_{it} \) (and differences of \( k_{it} \)) are used as instrumental variables, the inverse of the product of the instrument matrix is (close to) singular. However, the fact that capital does not change frequently means there is no strong correlation between \( k_{it} \) and \( w_{it} \).

\( ^{37}\)To circumvent the problem of weak instruments, Hahn, Hausman and Kuersteiner (2007) propose an alternative differencing estimator which uses “long differences” rather than first differences.


Industry,” *mimeo*.

nications Equipment Industry,” *Econometrica*, 64, 1263-1298.

sity Press.


metrica*, 56, 931-954.

erature*, 49(2), 326-365.


Industrial Economics*, 55, 529-569.

19, 568-588.

Figure 1: Cement Consumption and Construction Investment
Figure 2: Capacity and Production
Figure 3: Production Function
Table 1: The Cement Industry in Japan (1990-2010)
Capacity and Production are measured in terms of million tons. Firms, Plants, and Kilns are the number of firms, plants, and kilns, respectively.

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity</th>
<th>Production</th>
<th>Firms</th>
<th>Plants</th>
<th>Kilns</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>87.81</td>
<td>75.29</td>
<td>23</td>
<td>41</td>
<td>81</td>
</tr>
<tr>
<td>1991</td>
<td>89.29</td>
<td>80.13</td>
<td>22</td>
<td>41</td>
<td>80</td>
</tr>
<tr>
<td>1992</td>
<td>90.47</td>
<td>87.39</td>
<td>22</td>
<td>41</td>
<td>81</td>
</tr>
<tr>
<td>1993</td>
<td>98.04</td>
<td>87.44</td>
<td>22</td>
<td>41</td>
<td>81</td>
</tr>
<tr>
<td>1994</td>
<td>97.99</td>
<td>89.70</td>
<td>20</td>
<td>41</td>
<td>81</td>
</tr>
<tr>
<td>1995</td>
<td>97.57</td>
<td>89.10</td>
<td>20</td>
<td>41</td>
<td>81</td>
</tr>
<tr>
<td>1996</td>
<td>97.03</td>
<td>91.60</td>
<td>20</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>1997</td>
<td>95.95</td>
<td>88.46</td>
<td>20</td>
<td>39</td>
<td>75</td>
</tr>
<tr>
<td>1998</td>
<td>95.64</td>
<td>76.25</td>
<td>18</td>
<td>39</td>
<td>75</td>
</tr>
<tr>
<td>1999</td>
<td>95.59</td>
<td>74.26</td>
<td>18</td>
<td>38</td>
<td>75</td>
</tr>
<tr>
<td>2000</td>
<td>87.22</td>
<td>75.57</td>
<td>18</td>
<td>37</td>
<td>65</td>
</tr>
<tr>
<td>2001</td>
<td>83.31</td>
<td>71.78</td>
<td>18</td>
<td>36</td>
<td>65</td>
</tr>
<tr>
<td>2002</td>
<td>80.28</td>
<td>68.95</td>
<td>18</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>2003</td>
<td>78.50</td>
<td>66.91</td>
<td>18</td>
<td>35</td>
<td>62</td>
</tr>
<tr>
<td>2004</td>
<td>74.25</td>
<td>65.49</td>
<td>18</td>
<td>33</td>
<td>59</td>
</tr>
<tr>
<td>2005</td>
<td>70.21</td>
<td>66.80</td>
<td>17</td>
<td>32</td>
<td>58</td>
</tr>
<tr>
<td>2006</td>
<td>70.33</td>
<td>66.80</td>
<td>17</td>
<td>32</td>
<td>58</td>
</tr>
<tr>
<td>2007</td>
<td>69.78</td>
<td>60.63</td>
<td>17</td>
<td>32</td>
<td>57</td>
</tr>
<tr>
<td>2008</td>
<td>68.13</td>
<td>57.30</td>
<td>17</td>
<td>32</td>
<td>57</td>
</tr>
<tr>
<td>2009</td>
<td>63.44</td>
<td>50.25</td>
<td>17</td>
<td>32</td>
<td>57</td>
</tr>
<tr>
<td>2010</td>
<td>61.48</td>
<td>47.78</td>
<td>17</td>
<td>32</td>
<td>56</td>
</tr>
</tbody>
</table>
The Figures for Taiheiyo include those for its subsidiaries, DC, Mikawa-Onoda, Myojo, and Tsuruga. Similarly, those for Sumitomo-Osaka include Hachinohe and those for Aso include Kanda. Plants indicates the number of plants.

<table>
<thead>
<tr>
<th>Firm Name</th>
<th>Production Share (%)</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiheiyo</td>
<td>36.70</td>
<td>13</td>
</tr>
<tr>
<td>Ube Mitsubishi</td>
<td>25.25</td>
<td>9</td>
</tr>
<tr>
<td>Sumitomo Osaka</td>
<td>17.72</td>
<td>7</td>
</tr>
<tr>
<td>Tokuyama</td>
<td>6.18</td>
<td>1</td>
</tr>
<tr>
<td>Aso</td>
<td>2.93</td>
<td>2</td>
</tr>
<tr>
<td>Denka</td>
<td>2.69</td>
<td>1</td>
</tr>
<tr>
<td>Mitsui</td>
<td>2.36</td>
<td>1</td>
</tr>
<tr>
<td>Tosoh</td>
<td>1.90</td>
<td>1</td>
</tr>
<tr>
<td>Shinnittetsu</td>
<td>1.22</td>
<td>1</td>
</tr>
<tr>
<td>Nittetsu</td>
<td>1.15</td>
<td>1</td>
</tr>
<tr>
<td>Hitachi</td>
<td>1.00</td>
<td>1</td>
</tr>
<tr>
<td>Ryukyu</td>
<td>0.88</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3: Patterns of Cement Distribution

The Ube and Kanda plants are owned by Ube Cement Corp., which is one of the pre-merger firms of Ube-Mitsubishi Cement Corp. Figures come from the Cement Yearbook 1988. The distance from the production location to each region is shown in parentheses. This distance is defined as the distance between the nearest port of each plant to the largest port in each region (in terms of miles). Okinawa is excluded from this table.

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Location</th>
<th>Production</th>
<th>Hokkaido</th>
<th>Tohoku</th>
<th>Kanto</th>
<th>Hokuriku</th>
<th>Tokai</th>
<th>Kinki</th>
<th>Shikoku</th>
<th>Chugoku</th>
<th>Kyushu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ube</td>
<td>Chugoku</td>
<td>5.227</td>
<td>0.04</td>
<td>0.05</td>
<td>0.24</td>
<td>0.02</td>
<td>0.24</td>
<td>0.11</td>
<td>0.07</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(773)</td>
<td>(731)</td>
<td>(532)</td>
<td>(514)</td>
<td>(404)</td>
<td>(236)</td>
<td>(80)</td>
<td>-</td>
<td>(75)</td>
</tr>
<tr>
<td>Kanda</td>
<td>Kyushu</td>
<td>2.334</td>
<td>0.05</td>
<td>0.08</td>
<td>0.10</td>
<td>0.04</td>
<td>0.12</td>
<td>0.27</td>
<td>0.05</td>
<td>0.10</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(775)</td>
<td>(737)</td>
<td>(538)</td>
<td>(516)</td>
<td>(410)</td>
<td>(242)</td>
<td>(86)</td>
<td>(97)</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 4: Summary Statistics

There are 430 plant-year observations in 13 years (1998-2010). The units are million tons for production and plant size and tons for capital, while the unit is trillion yen for export demand. Labor is measured by the number of workers. Capacity reduction and exit are dummy variables, with the former indicating whether a plant reduced the number of kilns and the latter indicating whether a plant exited. Inland is a dummy variable indicating whether a plant is located in an inland area, while multi-plant indicates whether a plant is part of a multi-plant firm.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>1.946</td>
<td>1.520</td>
<td>0.231</td>
<td>8.082</td>
</tr>
<tr>
<td>Labor</td>
<td>112.640</td>
<td>62.860</td>
<td>31</td>
<td>372</td>
</tr>
<tr>
<td>Capital</td>
<td>758.003</td>
<td>502.862</td>
<td>202</td>
<td>2795</td>
</tr>
<tr>
<td>Capacity reduction</td>
<td>0.033</td>
<td>0.178</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Exit</td>
<td>0.021</td>
<td>0.143</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Plant size</td>
<td>2.347</td>
<td>1.622</td>
<td>0.434</td>
<td>8.355</td>
</tr>
<tr>
<td>Inland</td>
<td>0.256</td>
<td>0.437</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Multi-plant</td>
<td>0.805</td>
<td>0.397</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Export demand</td>
<td>23.964</td>
<td>4.752</td>
<td>17.2</td>
<td>32.7</td>
</tr>
</tbody>
</table>
Table 5: Cobb-Douglas Production Function Estimation

** significant at the 5% level.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>β_l</td>
<td>0.2848**</td>
<td>0.2401**</td>
<td>0.2119**</td>
</tr>
<tr>
<td></td>
<td>(0.0329)</td>
<td>(0.0402)</td>
<td>(0.0516)</td>
</tr>
<tr>
<td>β_k</td>
<td>0.9114**</td>
<td>0.4323**</td>
<td>0.1963**</td>
</tr>
<tr>
<td></td>
<td>(0.0292)</td>
<td>(0.0713)</td>
<td>(0.0788)</td>
</tr>
<tr>
<td>ρβ_l</td>
<td>-0.1244</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0757)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ρβ_k</td>
<td>-0.0568</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0537)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ρ</td>
<td>0.8971**</td>
<td>0.6450**</td>
<td>0.8273**</td>
</tr>
<tr>
<td></td>
<td>(0.0308)</td>
<td>(0.0512)</td>
<td>(0.0385)</td>
</tr>
<tr>
<td>Plant Fixed Effects?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time Effects?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>R²</td>
<td>0.8716</td>
<td>0.9705</td>
<td>n.a.</td>
</tr>
<tr>
<td>Observations</td>
<td>430</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6: Correlation Between Different Productivity Estimates for 1998

<table>
<thead>
<tr>
<th>(a) Correlations</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Cobb-Douglas (OLS)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Cobb-Douglas (FE)</td>
<td>0.597</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Cobb-Douglas (GMM)</td>
<td>0.434</td>
<td>0.979</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>(4) Nonparametric (FE)</td>
<td>0.566</td>
<td>0.981</td>
<td>0.975</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(b) Rank Correlations</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Cobb-Douglas (OLS)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Cobb-Douglas (FE)</td>
<td>0.681</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Cobb-Douglas (GMM)</td>
<td>0.510</td>
<td>0.964</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>(4) Nonparametric (FE)</td>
<td>0.683</td>
<td>0.978</td>
<td>0.935</td>
<td>1</td>
</tr>
</tbody>
</table>
The coefficients are the marginal effect of each variable (evaluated at the mean). The columns labeled “Reduction” show the marginal effect on the probability that the number of kilns is reduced. The columns labeled “Exit” show the marginal effect on the probability of exit. The marginal effect on the probability of no divestment is not reported here. Standard errors are presented in parentheses. The standard errors are clustered by plant and are calculated by block bootstrapping.

** significant at the 5% level; * significant at the 10% level.

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reduction</td>
<td>Exit</td>
<td>Reduction</td>
<td>Exit</td>
</tr>
<tr>
<td>Relative size</td>
<td>0.0057*</td>
<td>0.0032</td>
<td>0.0054*</td>
<td>0.0028</td>
</tr>
<tr>
<td></td>
<td>(0.0032)</td>
<td>(0.0020)</td>
<td>(0.0031)</td>
<td>(0.0019)</td>
</tr>
<tr>
<td>Relative efficiency</td>
<td>-0.1042**</td>
<td>-0.0589**</td>
<td>-0.1106**</td>
<td>-0.0578**</td>
</tr>
<tr>
<td></td>
<td>(0.0321)</td>
<td>(0.0247)</td>
<td>(0.0331)</td>
<td>(0.0253)</td>
</tr>
<tr>
<td>Inland</td>
<td>0.0145</td>
<td>0.0087</td>
<td>0.0108</td>
<td>0.0059</td>
</tr>
<tr>
<td></td>
<td>(0.0160)</td>
<td>(0.0129)</td>
<td>(0.0157)</td>
<td>(0.0124)</td>
</tr>
<tr>
<td>Export demand</td>
<td>-0.0008</td>
<td>-0.0005</td>
<td>-0.0008</td>
<td>-0.0004</td>
</tr>
<tr>
<td></td>
<td>(0.0009)</td>
<td>(0.0006)</td>
<td>(0.0009)</td>
<td>(0.0005)</td>
</tr>
<tr>
<td>Multi-plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Production function</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cobb-Douglas (OLS)</td>
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<td>Cobb-Douglas (FE)</td>
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Table 8: Effects on Probability of Divestment (2)

The coefficients are the marginal effect of each variable (evaluated at the mean). The columns labeled “Reduction” show the marginal effect on the probability that the number of kilns is reduced. The columns labeled “Exit” show the marginal effect on the probability of exit. The marginal effect on the probability of no divestment is not reported here. Standard errors are presented in parentheses. The standard errors are clustered by plant and are calculated by block bootstrapping.

** significant at the 5% level; * significant at the 10% level.

<table>
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<tr>
<th></th>
<th>Reduction</th>
<th>Exit</th>
<th>Reduction</th>
<th>Exit</th>
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<td>-0.0810**</td>
<td>-0.0448**</td>
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<td>-0.0075</td>
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<td>(0.0312)</td>
<td>(0.0332)</td>
<td>(0.0241)</td>
<td>(0.0525)</td>
<td>(0.0455)</td>
<td>(0.0597)</td>
<td>(0.0414)</td>
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<td>0.0057</td>
<td>0.0067</td>
<td>0.0057</td>
<td>0.0253**</td>
<td>0.0151**</td>
<td>0.0179**</td>
<td>0.0124**</td>
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<td>(0.0031)</td>
<td>(0.0048)</td>
<td>(0.0031)</td>
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<td>-0.0649**</td>
<td>-0.1175**</td>
<td>-0.0649**</td>
<td>-0.0734</td>
<td>-0.0451</td>
<td>-0.0842*</td>
<td>-0.0516</td>
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<td>(0.0318)</td>
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<td>(0.017)</td>
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<td>-0.0015</td>
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<td>(0.0009)</td>
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Table 9: Production Allocation Efficiency

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<th>Year</th>
<th>(1) Cobb-Douglas (OLS)</th>
<th>(2) Cobb-Douglas (FE)</th>
<th>(3) Cobb-Douglas (GMM)</th>
<th>(4) Nonparametric (FE)</th>
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<td>Total</td>
<td>Inter-firm</td>
<td>Intra-firm</td>
<td>Total</td>
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<td>0.923</td>
<td>0.969</td>
<td>0.952</td>
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<tr>
<td>2000</td>
<td>0.929</td>
<td>0.969</td>
<td>0.959</td>
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<tr>
<td>2001</td>
<td>0.948</td>
<td>0.970</td>
<td>0.977</td>
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<tr>
<td>2002</td>
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<td>0.970</td>
<td>0.869</td>
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<td>0.975</td>
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<td>0.885</td>
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<tr>
<td>2005</td>
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<td>0.972</td>
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<td>0.946</td>
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