Studies on understanding the nature of competition

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(日本の市場競争環境についての実証研究)

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Abstract

This dissertation consists of two empirical studies and one literature survey in the field of empirical industrial organization. In each of the two empirical studies, I have developed an empirical method for understanding the nature of competition in an industry and provide an application based on the method.

Chapter 1 is devoted to organizing the studies that are methodologically closely related to the two empirical studies and their method.

Chapter 2 is a study of the competitive environment of the Japanese intercity coach industry using data on the entry behavior of bus companies. This study is unique in that it estimates an entry model that allows for product differentiation by supplementing data on entry behavior with data on market-level demand, which is made possible by modifying the contribution of Schaumans and Verboven (2014). Controlling for the possibility of product differentiation, I reveal the existence of market competition in the industry. This chapter is a modified version of Mizuta (2020).[1]

Chapter 3 is a study of the noncooperative entry deterrence behavior of Japanese aluminum smelting firms. To study this, I develop an empirical model of entry deterrence based on Gilbert and Vives (1986) and show an identification result on marginal cost with which firms engage in strategic entry deterrence. Employing a Voung type model selection test, I reveal that the firm conduct in the industry is consistent with strategic entry deterrence behavior.

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[1] I have confirmed with Elsevier, which holds the copyright of Mizuta (2020), that there are no copyright issues in including a modified version of the paper in this dissertation.

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Chapter 1

Introduction

This dissertation contributes to two strands of literature on the empirical industrial organization (henceforth empirical IO), the estimation of entry model and the conduct testing literature, by providing two empirical studies. Both the entry model and conduct testing are devised to understand the nature of competition in an industry.

Examining the nature of competition is a central issue in empirical IO for several reasons. First, it is an independent interest for the possibility of collusive behavior in oligopolies. Since collusion is usually regarded as the supreme evil of antitrust (Asker and Nocke, 2021), detecting such behavior by examining the competition in an industry and devising or developing empirical methods to understand competition is an important mission for researchers in empirical IO. Second, the nature of competition is a fundamental input for policy analysis. Researchers in empirical IO frequently "assume" the model of competition for examining the effect of a counterfactual policy on a specific industry: a so-called counterfactual analysis. If the assumed model of competition does not capture the reality of the industry, the effect estimated or simulated will be biased. Therefore, understanding the nature of competition is also important from the viewpoint of policy analysis.

This dissertation contributes to the literature in two senses. First, both Chapters 2 and 3 reveal the nature of competition in two Japanese industries. As noted above, revealing the nature of competition is an independent interest for both antitrust policymakers and researchers. Antitrust policymakers could refer to the result as a piece of evidence about collusive behavior in the industries. Researchers could use this finding about the competition in the two Japanese industries in future empirical studies that adopt a structural approach. Second, both Chapters 2 and 3 modify or develop an econometric method for understanding the nature of competition. More specifically, I modify the contribution of Schaumans and Verboven (2014) to use quantity data instead of sales data so that similar

studies like theirs can be done in Chapter 2. In Chapter 3, I develop a structural model of entry deterrence to test whether firms in an industry engage in noncooperative entry deterrence. Therefore, this dissertation has empirical and methodological contributions.

There is not just one but many different methods to understand the nature of competition, as suggested by the fact that this study employs two different methods. This is because the data environments faced by researchers and practitioners vary: not all economic quantities are observable. Since researchers in empirical IO have been trying to develop empirical methods even if ideal data are not available, there exist several empirical methods to examine an industry competition. From the viewpoint of data requirements, the empirical model of firm entry is designed to allow for empirical analysis even in situations where ideal data are not available. On the other hand, the conduct testing is a method that researchers rely on when they can employ ideal data which includes price and demand data. Intuitively, the weaker the data requirements become, the stronger the assumptions are required to understand the nature of competition, and the smaller the industry or market to which the method can be applied become. Therefore, although the data requirements of an empirical model of firm entry are small, this does not necessarily mean that it has a wide range of applications.

Since there is a tradeoff between the requirements of data and assumptions, researchers must recognize why and when empirical methods can reveal the nature of competition. Therefore this chapter is devoted to surveying the two literature and clarifying why and when the two methods which I rely on in the later chapters can reveal the nature of competition. By clarifying this, this chapter has a role to complement the methodological explanation of the two later empirical studies. Therefore, I elaborate on several studies that have methodological and conceptual contributions, while I also review the two literature including applied studies, and locate the two later chapters in those studies. Lastly, I note that the two methods reviewed in this chapter do not cover all methods to understand the nature of competition.[1]

1.1 Literature review

1.1.1 Empirical models of entry

Various empirical (or econometric) models of firm entry have been developed since the 1980s. These models employ data on the entry behavior of firms in a market to estimate

[1]For example, I do not cover the studies on detecting collusion or bid-rigging in an auction. The literature includes Porter and Zona (1993), Bajari and Ye (2003), Ohashi (2009), and Kawai and Nakabayashi (2022). These kinds of literature use auction-firm level bidding data to detect bid-rigging.

the firms' profit function. Since the profit is essentially a function of market structure (i.e., the number of firms in a market and the identity of entering firms in general) or a rival's action, estimating it can reveal the nature of competition. Furthermore, since firms in a market must have decided to enter the market based on the profit they can make, the entry behavior of the firms contains information about the profit, and we may be able to estimate the profit function using the data on entry behavior.

Behind the estimation of entry model, it is assumed that the firms in a market can possess market power if they enter. In other words, the entry model is a model for analyzing the decision of firms in a strategic environment, not for analyzing the decisions of firms in a perfectly competitive market. If researchers could impose the assumption of perfect competition on an industry, they would not need to infer the nature of competition in that industry from the entry behavior.

Because of the strategic interaction behind an empirical model of firm entry, it generally has a property called "incompleteness", which makes the estimation of a model difficult. In accordance with Tamer (2003) and Manski (1988), "an incomplete econometric model is one where the relationship from (x, u) to y is a correspondence and not a function". In their definition, x and u are observable and unobservable random vectors, respectively, and y is an observable random vector, which is endogenously determined by a system of equations.[2]

To understand why an entry model becomes an incomplete one and why it makes estimation difficult, it is appropriate to analyze an entry model presented by Bresnahan and Reiss (1991b). In their model, two potential entrants, firms 1 and 2, exist in a market m. Firm $i \in \{1, 2\}$ decides whether to enter ($y_{mi} = 1$) or not to enter ($y_{mi} = 0$) the market without knowing the rivals' strategy: simultaneous move game. When firm i decides to enter a market, it earns

$$\Pi_{mi} = x'_{mi}\beta_i - \Delta_i 1[y_{mj} = 1] - u_{mi},\ i \in \{1, 2\},\ j \neq i,$$

where x_{mi} includes the variables which affects the (monopoly) profit of firm i, and u_{mi} represents the unobserved portion of profit.[3] $1[.]$ represents an indicator function which takes 1 if the argument in the parenthesis is true and otherwise 0. The profit which firm i earns when it does not enter is normalized to be zero.[4] The goal of an empirical analysis is to estimate the parameter (β_i, Δ_i) employing cross-section data for several markets.

[2]As to the definition of an econometric model, see Matzkin (2007).

[3]Because the game is an complete information game, firm j knows the value of u_{mi}, but a researcher or econometrician cannot know the value.

[4]See Train (2009) for details on normalization of utility or payoff on a single-agent discrete choice model.

Especially, since Δ_i measures how the monopoly profit of firm i is decreased by the entry of rival j, estimating it reveals the nature of strategic interaction between the firms. The pay-off matrix of the game is given by Table 1.1.

Table 1.1: Payoff martix of the two-player game

	$y_{m2} = 0$	$y_{m2} = 1$
$y_{m1} = 0$	$(0, 0)$	$(0, x'_{m2}\beta_2 - u_{m2})$
$y_{m1} = 1$	$(x'_{m1}\beta_1 - u_{m1}, 0)$	$(x'_{m1}\beta_1 - \Delta_1 - u_{m1}, x'_{m2}\beta_2 - \Delta_2 - u_{m2})$

A standard procedure to estimate the parameters in an econometric model is maximum likelihood estimation. A maximum likelihood estimation requires researchers to specify the distribution of error terms in a model and to calculate the conditional probability of each observation. In the case of entry models, the error term may be specified to follow the standard normal distribution,[5] i.e. $u_{mi} \sim N(0, 1)$, $\forall i \in \{1, 2\}$, and the conditional probability of observing a market structure $P(y_{m1}, y_{m2}|x_{m1}, x_{m2}; \beta_1, \beta_2, \Delta_1, \Delta_2)$ is required to be calculated. However, the conditional probability cannot be calculated even if the distributions of error terms are specified. To see this, let the value of error terms satisfy

$$x'_{mi}\beta_i - \Delta_i < \epsilon_i < x'_{mi}\beta_i, \forall i \in \{1, 2\}. \tag{1.1}$$

When the conditions are satisfied, there exist two Nash equilibria in the game: $(y_{m1}, y_{m2}) = (1, 0), (0, 1)$. If the game has multiple Nash equilibria, since we cannot predict which Nash equilibrium will be realized in the data, calculating the conditional probability is infeasible. Although I have only considered an example of a two-player entry game here, the same property holds even if the number of players in a game increases. Namely, the multiplicity of equilibria in a game-theoretic model makes an econometric model incomplete and prevents estimation by the maximum likelihood method. Bresnahan and Reiss (1991b) call these models "ill-defined probability models" rather than incomplete models.

To overcome the incompleteness of an entry game, various solutions have been proposed in previous studies. Berry and Reiss (2007, p.1867) categorizes the solutions into the following four categories.

1. to model the probabilities of aggregated outcomes that are robust to the multiplicity of equilibria.

2. to place additional conditions on the model that guarantee a unique equilibrium.

[5]The reason why not a normal, i.e. $u_{mi} \sim N(0, \sigma)$, but the standard normal distribution, i.e. $u_{mi} \sim N(0, 1)$ is assumed is for normalization. See Train (2009).

3. to include in the estimation additional parameters that "select" among multiple equilibria.

4. to accept that some models with multiple equilibria are not exactly identified.

I review examples of each of these four solutions in the following subsections, however, I especially elaborate on the first solution above since it is the approach on which Chapter 2 of this dissertation relies.

Using the number of firms in a market: aggregated outcomes

The intuition behind the first approach can be understood in the following way. The two-player entry game analyzed above does not uniquely predict the equilibrium (y_{m1}, y_{m2}) due to the multiplicity of the game, therefore we cannot calculate the conditonal probability $P(y_{m1}, y_{m2}|x_{m1}, x_{m2})$. Here, we can turn our attention to the number of entrant $N_m = \sum_i y_{mi}$ rather than the equilibrium itself. Even if the error terms (u_{m1}, u_{m2}) satisfy the condition where multiple equilibria exist, the number of firms entering a market is one in both equilibria in the two-player entry game. Therefore, we can construct the conditional probability of the number of firms in a market $P(N_m|x_{m1}, x_{m2})$ rather than $P(y_{m1}, y_{m2}|x_{m1}, x_{m2})$. While the number of firms is robust to multiplicity in the two-player entry game, even if any additional restrictions are not imposed on the profit function, it is not the case if a model becomes more general, i.e. more than two potential entrants. Several studies reveal the condition when the number of firms is robust to the multiplicity of equilibria.

Berry (1992) considers an entry game where more than 2 potential entrants are players of the game. He restricts the profit function as:

$$\begin{aligned}\Pi_{mi} &= \Pi_{mi}(y_{m1}, y_{m2}, ..., y_{mK_m}) \\ &= v_m(\sum_{i=1}^{K_m} y_{mi}) + \phi_{mi}\end{aligned}$$

where K_m is the number of potential entrants, $v_m(.)$ is a component of profit which are common between firms in market m, and ϕ_{mi} represents a firm-specific profit component. The profit function has a feature that Π_{mi} is not affected directly by rivals' actions but only affected by them via the equilibrium number of firms. Berry (1992, p.894) proves that given the profit function, all pure strategy Nash equilibria in market m involve a unique number, N, of entering firms. The contribution of Berry (1992) is not restricted to deriving the condition on a unique outcome. Because the conditional probability of

observing N has a very complicated form, Berry (1992) proposes a simulated method of moment estimator to estimate the parameters of the game. The application of Berry (1992)'s approach includes Jia (2008) and Takahashi (2015).

Bresnahan and Reiss (1991a) also reveal a condition where the number of firms is robust to the multiplicity of equilibria. While Berry (1992) considers a specification of profits which allows the heterogeneity between entrants, Bresnahan and Reiss (1991a) consider a more restricted one. Instead of making more restrictive assumptions on firm profits, they not only enable the estimation which utilizes the equilibrium number of firms rather than the equilibrium itself just like Berry (1992) but also derives from the model a useful measure from which we can infer the nature of competition in an industry. They specify the profit of an entrant as:[6]

$$\Pi_{mi} = \pi_m(N) - F_m, \tag{1.2}$$

where $\pi_m(N)$ represents a variable profit and F_m represents a fixed cost. This specification assumes that firms in a market are completely homogeneous in profits and therefore the variable profit of firm i is only affected by the other firms action via the equilibrium number of firms. Furthermore, Bresnahan and Reiss (1991a) assume that there are many or at least $N_m + 1$ firms as potential entrants in market m. With the model, it is clear that there exist multiple Nash equilibria while the number of firms is unique between the equilibria. Therefore if we specify the distribution of the variable profit and fixed cost[7], the maximum likelihood estimator can be applied. The conditional probability of observing that $N^* > 0$[8]firms enter market m is

$$\begin{aligned} Prob[N_m = N^*] &= Prob[\pi_m(N^*) - F_m > 0, \pi_m(N^* + 1) - F_m < 0] \\ &= Prob[\pi_m(N^* + 1) < F_m < \pi_m(N^*)]. \end{aligned}$$

Specifically, if we specify that F_m follows a normal or logistic distribution, the estimation of this entry model reduces to that of a well-known ordered probit or logit model.

Bresnahan and Reiss (1991a) derive a useful measure which helps us understand the nature of competition by imposing more restrictive form on profit than (1.2). They consider

[6]The notation here is based on Berry and Reiss (2007) rather than Bresnahan and Reiss (1991a).

[7]As far as the author knows, the fixed cost term is specified to have unobserved random factors, while the distribution of variable profit is specified to degenerate in the literature.

[8]The probability that no firms enter the market m is calculated as : $Prob[F_m < \pi_m(1)]$.

a market whose demand has the form

$$Q_m(P) = S_m \times d_m(P),$$

where $Q_m(P)$ is the market level demand function, $d_m(P)$ is the demand function of a "representative consumer", and S_m represents the market size or the number of consumers in a market. Since the market size does not affect the equilibrium price given any number of firms in a market, the multiplicative structure of the demand function enables the profit function (1.2) to be rearranged as:

$$\begin{aligned}\Pi_{mi} &= S_m \times (p_m(N) - c_m)q_m(N) - F_m \\ &= S_m \times v_m(N) - F_m,\end{aligned}$$

where $p_m(N)$, $q_m(N)$, and $v_m(N)$ represents the per capita price, demand, and variable profit when N firms exist in a market, respectively.

When the profit function has the structure represented above, the Entry Threshold Ratio (henceforth ETR) defined below measures how variable profits earned by the industry decrease due to an additional one firm entry.

$$\begin{aligned}ETR_m(N) &= \frac{s_m(N)}{s_m(N-1)},\ N \in \{2,3,4,...\},\ \text{where} \\ s_m(N) &= S_m(N)/N,\ N \in \{1,2,3,...\} \text{ and} \\ S_m(N) &= F_m/v_m(N),\ N \in \{1,2,3,...\}.\end{aligned}$$

Here $S_m(N)$ and $s_m(N)$ are called the entry threshold and per firm entry threshold, respectively. This is because the entry threshold $S_m(N)$ represents the minimum market size necessary for N firms can profitably enter market m. Namely, $S_m(N)$ solves $\Pi_{mi} = S \times v_m(N) - F_m = 0$ for market size S. A calculation reveals that $ETR_m(N)$ corresponds to $\frac{V_m(N-1)}{V_m(N)}$, where $V_m(N) = v_m(N) \times N$ represents the per capita "industry" variable profit with N firms. Therefore, if $ETR_m(N)$ takes a value larger than one, the industry variable profit is decreased by the Nth firms entry, i.e. $V_m(N) < V_m(N-1)$. On the other hand, if $ETR_m(N)$ is estimated to be one, this means the industry variable profit is not affected by the Nth firm entry. In other words, we can reveal the competitive effects of Nth firm entry and the presence of competition in a market by estimating the ETR in a market.

Although ETR itself can be defined in the same way for a specification of the profit function that includes a market size variable in some other form, it is the multiplicative structure of the demand function that allows the ETR to measure changes in the industry

variable profit. Since the value of ETR generally depends on the identity of market or market demographics, Bresnahan and Reiss (1991a) shows the value of ETR evaluated at the sample mean of market demographics rather than a specific market in the sample.

Schaumans and Verboven (2014) extends the model of Bresnahan and Reiss (1991a) to allow for differentiated products settings utilizing market-level revenue data. Schaumans and Verboven (2014) point out that "a central assumption of Bresnahan and Reiss's methodology is firms produce homogeneous products: holding prices constant, an additional entrant leads only to business stealing and does not create market expansion". To allow for the market expansion effect of an additional entry, they specify demand function as:

$$Q_m(P, N) = S_m \times d_m(P, N). \tag{1.3}$$

The difference between the demand function specified by Bresnahan and Reiss (1991a) and Schaumans and Verboven (2014) is that the latter includes the number of firms in a market as its argument. In a differentiated products market, new product offerings increase the variety of products available for consumers and the possibility to purchase goods according to individual preferencess. Therefore, the demand in a differentiated products market may increase when new product offerings occur even if the prices remain the same. The demand function represented by equation (1.3) can capture this possibility when the condition $\partial Q_m(P, N)/\partial N > 0$ holds.

They contribute to the literature in several ways. First, they show that even if entry leads to a price decrease ($dp_m(N)/dN < 0$), $ETR_m(N)$ takes a value smaller than 1 when products are sufficiently differentiated (Schaumans and Verboven, 2014, Proposition 2). In other words, they reveal that $ETR_m(N)$ cannot be used for inferring the nature of competition in a differentiated products market. Second, they show that we can estimate another measure for inferring the nature of competition rather than $ETR_m(N)$ when market-level revenue data are available. The measure they propose can be used in the same way as the $ETR_m(N)$: if the measure takes a value larger than one, we can reveal the competitive effects of an entry.

Chapter 2 of this dissertation is the most relevant to Schaumans and Verboven (2014). While Schaumans and Verboven (2014) develops a method to account for product differentiation using market-level revenue data, Chapter 2 of this dissertation modifies their method to use market-level demand data rather than revenue. To the best of my knowledge, the formal presentation of the modification does not exist in the literature, though the possibility of using demand rather than revenue data is noted in Schaumans and Ver-

boven (2014). Therefore, Chapter 2 of this dissertation has a contribution not only as an estimation of empirical models of firm entry in differentiated products market but also as a formal presentation of the Schaumans and Verboven (2014)'s type entry model utilizing demand data. See Chapter 2 for a derivation and discussion of the measure employed to understand the competition in a differentiated products market.

The other approaches to estimate entry models

Back to the general entry model represented by Table 1.1, I review the other three approaches to estimate an entry model.

Additional condition on the game The second solution is to place additional conditions on the model that guarantee a unique equilibrium. In the two-player entry game, there exist two Nash equilibria when condition (1.1) holds. Now suppose that we can assume that firm 1 moves first. Namely, the assumption changes the simultaneous two-player entry game to the sequential two-player entry game. While the simultaneous game cannot uniquely predict the entry behaviors of the two potential entrants when condition (1.1) holds due to the multiplicity, the sequential game predicts that firm 1 enters the market and firm 2 stays out $(y_{m1}, y_{m2}) = (1, 0)$ when condition (1.1) holds. If condition (1.1) does not hold, then the sequential game makes the same predictions as the simultaneous game. Therefore, the assumption that firm 1 moves first solves the incompleteness of the simultaneous model.

The assumption of sequential move inevitably favors firm 1, because it assumes that firm 1 can enter whenever condition (1.1) is satisfied. Instead of the assumption, the assumption that the firm with the higher profit can enter also ensures the uniqueness of the two firms' entry behaviors. What these two assumptions (first move by firm 1 or the more profitable firm) have in common is that if multiple equilibria arise, one of the equilibria will be chosen by some arbitrary criterion that a researcher imposes. Several studies employ the method of imposing an additional structure into the game. For example, Mazzeo (2002b) constructs an entry model in which potential entrants can choose product type (high or low quality) when they enter. Because the model has incompleteness for the equilibrium product-type configuration[9], a rule which decides the product-type configuration when the model does not make a unique prediction is introduced to enable maximum likelihood estimation. Igami (2017) and Igami and Uetake (2019) utilize a

[9]The product type configuration means the number of low-quality and high-quality firms denoted by (L, H) in the study.

sequential move game formulation to guarantee a unique equilibrium and maximum likelihood estimation, although those are not classified in the static entry game literature.

Estimating equilibrium selection mechanism The third solution to the multiplicity of equilibria is to specify and estimate an equilibrium selection probability. This approach is explored by Bjorn and Vuong (1984) and extended by Bajari et al. (2010). The third approach, unlike the first, does not require a functional form restriction on the profit function in order to use an aggregate outcome, and unlike the second, does not assume the structure of the entry game. For example, in the two-player entry game described in Table 1.1, a version of this approach assigns probabilities $\lambda(x_{1m}, x_{2m}; \theta)$ and $1 - \lambda(x_{1m}, x_{2m}; \theta)$ to each of the two equilibria and attempts to estimate the parameters governing selection probabilities, θ, with the parameters of profit functions.

Why can the equilibrium selection probability or its parameters be estimated? Bajari et al. (2010, Theorem 2 on p. 1549) prove that the equilibrium selection probabilities can be identified in a general discrete game rather than two-player entry I have reviewed in this Chapter. The intuition of their identification result can be understood in the two-player entry game as follows. When the selection probability is introduced in the model, the probability of observing firm 1 monopoly satisfies the equation:

$$\begin{aligned} &Prob[\text{observing firm 1 monopoly}|x_m; \beta, \Delta, \lambda(x; \theta)] = \\ &\quad \lambda(x; \theta) \times Prob[(1,0) \text{ and } (0,1)|x_m; \beta, \Delta] + Prob[(1,0)|x_m; \beta, \Delta]. \end{aligned} \tag{1.4}$$

Here I denote the explanatory variables as $x_m = (x_{m1}, x_{m2})$ and the same notation is used for the parameters. In addition, $Prob[(1,0)|x_m; \beta, \Delta]$ represents the probability that $(y_{m1}, y_{m2}) = (1,0)$ becomes a "unique" Nash equilibrium and $Prob[(1,0) \text{ and } (0,1)|x_m; \beta, \Delta]$ represents the probability that the multiple equilibria arise.

Their identification strategy involves two steps. Firstly, they rely on the identification at infinity approach to identify the parameters of profit functions β and Δ.[10] Given the identification of β and Δ, the probabilities of $Prob[(1,0) \text{ and } (0,1)|x_m; \beta, \Delta]$ and $Prob[(1,0)|x_m; \beta, \Delta]$ are identified. Since the probability of observing firm 1 monopoly is directly identified from the data, the selection probability $\lambda(x; \theta)$ can be identified from equation (1.4). Although this approach is general in the sense that researchers need not

[10] I do not explicitly treat the identification at infinity approach as a solution to the incompleteness of an entry game in this chapter. The intuition behind the approach is that it focuses on samples of non-game theoretic situations and reduces the identification problem of the entry game to that of the single-agent discrete choice model. In the two-player game, firm 1 can make decisions as if it were a monopolist when the variables that firm 2 has are so unfavorable that firm 2 will not enter regardless of firm 1's decision. See Tamer (2003) for details of this approach.

restrict profit function or impose an additional game structure, the approach surely has shortcomings. The larger the number of potential entrants becomes, the more frequently the case where the multiplicity of equilibria arises increases. Therefore, we need to include many parameters to model equilibrium selection when the number of firms increases. This is a potential shortcoming for this approach (Berry and Reiss, 2007). The application of this approach includes Bajari et al. (2010), which study entry decisions by construction contractors to bid on highway projects in California and Nishiwaki (2012), which studies the strategic interaction between Japanese major three airlines.

Bound estimation The last solution to overcome the incompleteness of an entry game is a bound estimation. The bound estimation (Manski, 1995) is an econometric method that can be applicable for a variety of econometric problems, rather than being developed to overcome the incompleteness of an econometric model.[11] In the bound estimation, any strong assumptions which guarantee the point identification of a parameter are not imposed, unlike the three approaches which I have reviewed above.[12]

Without strong assumptions, the parameters in an incomplete econometric model are not point-identified in general, however, there are cases where the qualitative restrictions behind the model may still identify a non-trivial set of parameters rather than a single point and the set-identified (or partially-identified) parameters are still useful for testing a hypothesis of interest (Berry and Reiss, 2007). For example, the two-player entry model has the following four restrictions even any additional assumptions are not imposed.

$$Prob[\text{observing duopoly}] = Prob[(1,1)|x_m;\beta,\Delta] \tag{i}$$

$$Prob[\text{observing no entry}|x_m;\beta,\Delta] = Prob[(0,0)|x_m;\beta,\Delta] \tag{ii}$$

$$\begin{aligned} &Prob[(1,0)|x_m;\beta,\Delta] \\ &\quad \leq Prob[\text{observing firm 1 monopoly}] \\ &\quad \leq Prob[(1,0) \text{ or } (0,1)|x_m;\beta,\Delta] + Prob[(1,0)|x_m;\beta,\Delta] \end{aligned} \tag{iii}$$

$$\begin{aligned} &Prob[(0,1)|x_m;\beta,\Delta] \\ &\quad \leq Prob[\text{observing firm 2 monopoly}] \\ &\quad \leq Prob[(1,0) \text{ or } (0,1)|x_m;\beta,\Delta] + Prob[(0,1)|x_m;\beta,\Delta] \end{aligned} \tag{iv}$$

[11]The studies on bound estimation and partial (or set) identification began when Charles F. Manski began to study the basic probabilistic structure of the selection problem associated with survey non-response. The early and recent studies not limited to applications in empirical IO are surveyed in Manski (1995) and Molinari (2020), respectively.

[12]One may think that the third approach is highly general and does not impose strong assumptions. However, for example, equation (1.4) assumes that the equilibrium selection probability $\lambda(x;\theta)$ does not depend on any unobservables.

On the one hand, since the two-player entry model can predict the duopoly and no-entry probabilities given the parameter values, equalities (i) and (ii) hold. On the other hand, the model cannot predict the probability of firm 1 (or 2) monopoly due to the incompleteness. However, the model can predict the maximum and minimum probability of firm 1 (or 2) monopoly. More specifically, inequality (iii) means that the probability of firm 1 monopoly reaches the maximum when firm 1 always can enter the market in the case of multiple equilibria and that it reaches the minimum when firm 1 always cannot enter the market in the case of multiple equilibria.

The qualitative restrictions from a model enable researchers to impose inequality constraints on the population moments in the model like equations (i) to (iv) and to specify the model as a moment inequality model. The set of parameters satisfying the moment inequalities is called the identified set and the maximum and minimum values which are consistent with the restrictions are called upper and lower bounds on a parameter, respectively.

There are several estimation approaches for the partially-identified parameters in the literature. When the lower and upper bounds on a parameter are explicitly represented by a function of population moments, the bounds are estimated by its sample analog. The approach is adopted, for example, Manski (1995) and Okumura and Usui (2014). On the other hand, the bounds of parameters of interest are not necessarily represented by population moments and this is the case for the estimation of entry models. In this case, set-identified parameters are estimated by the estimation method of moment inequality models. Ciliberto and Tamer (2009) estimate an entry model of US airline industry in the set identification setting using the estimation method developed by Chernozhukov et al. (2007).

1.1.2 Conduct testing

This section reviews studies that rely on detailed market-level and/or firm-level data with information on prices, quantities sold, or characteristics of products, rather than data on firms' entry behavior.

The conduct parameter method

The empirical literature that tries to uncover the nature of competition from a set of market data dates back to so-called conduct parameter method (henceforth CPM), including Iwata

(1974), Bresnahan (1982), and Porter (1983).[13] While there are several versions of the CPM, they estimate a parameter that can be interpreted as the competitiveness of a market in common. A version of the CPM, for example Bresnahan (1982), assumes a homogeneous product market and N homogeneous firms in the market and consider the following equation.

$$P_t + \lambda P'(Q_t; Y_t, Z_t)Q_t = MC(Q_t; W_t). \tag{1.5}$$

Here P_t and Q_t are price and quantity in a market, W_t is observables which affect production cost, and (Y_t, Z_t) are both observables that affect demand. $P(Q_t)$, $MC(Q_t, W_t)$, and $MR(Q_t) = P(Q_t) + P'(Q_t)Q_t$ are inverse demand, (aggregated) marginal cost function, and (monopolist's) marginal revenue function, respectively. λ represents a conduct parameter. Bresnahan (1982) calls equation (1.5) the supply relation.

This equation can be viewed as a generalization of the first-order conditions of the firms' maximization problem in several forms of competition. First, the conduct parameter takes the value of 0, when firms are price takers. Second, when firms engage in a perfect cartel, the conduct parameter is equal to 1 since firms set market price to satisfy the equation $MR = MC$. Third, when there is some element of market power, λ takes an intermediate value between 0 and 1 since firms cannot set price to satisfy $MR = MC$ and the market price satisfies $MR < MC$. For example, the conduct parameter is equal to $1/N$ in a Cournot equilibrium. Therefore, the equation can be viewed as a generalization of several forms of competition and past IO economists engaged in estimating the conduct parameter.

The estimation of the conduct parameter is, for example, as follows. Bresnahan (1982) specify a linear demand function and marginal cost function as:

$$\begin{aligned} Q_t(P_t; Y_t, Z_t) &= \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t + \alpha_3 P_t Z_t + \alpha_4 Z_t + \epsilon_t, \\ MC(Q_t; W_t) &= \beta_0 + \beta_1 Q_t + \beta_2 W_t + \eta_t. \end{aligned} \tag{1.6}$$

Given the specification, equation (1.5) can be rearranged as:

$$P_t = -\lambda \frac{Q_t}{\alpha_1 + \alpha_3 Z_t} + \beta_0 + \beta_1 Q_t + \beta_2 W_t + \eta_t. \tag{1.7}$$

Given the demand parameter is identified and estimated[14], the equation includes two

[13]The term "conduct parameter method (CPM)" is used in Corts (1999). The approach is sometimes called "conjectural variation approach".

[14]Since the demand function includes two endogenous variables, P_t and $Q_t^{**} = P_t Z_t$, for identifying the parameters of the demand function, the availability of at least two cost shifters is sufficient.

endogenous variables, Q_t and $Q_t^* = \frac{Q_t}{\alpha_1+\alpha_3 Z_t}$. On the other hand, there are two excluded exogenous variables, Y_t and Z_t. Therefore, the conduct parameter is identified as the coefficient of Q_t^*. When Q_t^* is replaced with $\hat{Q}_t^* = \frac{Q_t}{\hat{\alpha}_1+\hat{\alpha}_3 Z_t}$, the conduct parameter can be estimated in the two-stage least square estimation of equation (1.7).

Although the CPM was widely applied by past empirical IO studies in the 1980s and 1990s, it is not in use now because it has become clear that the consistent estimation of a conduct parameter is difficult, being revealed by Corts (1999) or Puller (2009), among others.

Puller (2009) clearly shows the cause of the difficulties in a regression framework. He assumes a homogeneous product market and heterogeneous firms in production cost. With the heterogeneous firms setting, Puller (2009) considers an environment where the heterogeneous firms engage in efficient tacit collusion and derive a pricing equation like (1.7). While equation (1.7) only includes cost shock η_t as a regression error term, the pricing equation derived by Puller (2009) includes not only the cost shocks but also a term that depends on both cost and demand conditions as a regression error term when the heterogeneous firms engage in efficient tacit collusion. The inclusion of the demand conditions as an error term prevents excluded instruments, such as demand shifters, from identifying the conduct parameter. It is not only theoretically revealed that the CPM does not work, but also empirically revealed by Genesove and Mullin (1998) and Kim and Knittel (2006), among others.

Conduct Testing

In response to the criticism of the CPM, empirical IO researchers have now adopted a different approach, called "Conduct Testing".[15] This approach does not take the direct approach of estimating parameters that represent the degree of competition in an industry as the CPM does. Instead of directly estimating the nature of competition, this approach tries to understand the nature of competition by testing whether a specific model of competition can explain the data better than another model of competition. Through many tests, researchers look for the model that best explains the data.

The common procedure of the conduct testing literature is the following. First, researchers consider a set of competing models of competition that seem to be appropriate for describing the industry competition. Second, marginal costs are recovered from

[15] I use the term "conduct testing" to represent the approach or method which utilizes Vuong-type model selection test to understand the nature of competition. Backus et al. (2021) seem to use the term in a broader sense that includes the CPM. Because of the prevalence of the Vuong-type model selection test, I use the term in the narrow sense.

the first-order condition which characterizes the equilibrium of a model in the set of competing models. For example, if Cournot competition is assumed in a homogeneous product and heterogeneous firms market, marginal costs are recovered from the equation: $MC = \text{price} \times [1 + \frac{\text{a firm's production share}}{\text{price elasticity}}]$.[16] Third, using the recovered marginal costs and observable cost shifters, a cost function or a supply relation is estimated, which gives the residual of the estimation. Fourth, taking any two models from the set, utilizing the residuals from the two estimated marginal cost functions, a Vuong-type model selection test, specifically Vuong (1989) or Rivers and Vuong (2002), is executed to compare the two models and to determine which one of the two is better.[17]

The earliest contribution on this literature includes Bresnahan (1987) and Gasmi et al. (1992).[18] These two are conduct testing studies on the collusion of firms. Unlike the CPM, which only estimates the parameter that summarizes the industry competition, the conduct testing method allows researchers to work with more complex models. Therefore, the application of this method is not limited to collusion. For example, the application includes vertical supply relationships (Sudhir, 2001; Villas-Boas, 2007), imports threat (Salvo, 2010), collusion on advertising (Gasmi et al., 1992), order of entry (Gayle and Luo, 2015), price or quantity competition (Feenstra and Levinsohn, 1995), and price discrimination (D'Haultfœuille et al., 2019). The impact of common ownership on competition has received much attention in recent years, and Backus et al. (2021) test the common ownership hypothesis using market data and institutional holding data from the US serial industry.

Although the conduct testing method has been widely employed in the literature, the formal foundation for discriminating between alternative models of oligopoly competition in a "general" setting has not been well understood until recently. In other words, the empirical IO literature has a limited understanding of why data reveal firm conduct. More specifically, the IO literature reveals why data reveal firm conduct only in the setting where a homogeneous product demand and symmetric firms are assumed. Bresnahan (1982) and Lau (1982) consider the limited setting and Bresnahan (1982) introduces the notion of "demand rotation" and reveals that the demand rotation is the key for identifying firm

[16] If a differentiated products market is assumed, marginal costs also can be recovered from the first-order condition of an assumed model. See for example Nevo (2001).

[17] Detail on the test statistic and its calculation are explained in Chapter 3 of this dissertation.

[18] In fact, Bresnahan (1987) utilizes the Cox test rather than the Vuong-type model selection test, therefore it may not be included in my restricted definition of conduct testing. Like the Vuong-type model selection test, the Cox test has the characteristics of comparing two models. Therefore, I categorize the contribution of Bresnahan (1987) into the conduct testing literature. A distinction between the two tests is that the Cox test needs the assumption that one of the two models being compared is the correct model, unlike the Vuong-type model selection test.

conduct. Recall the setting introduced in the description of the CPM above and see the demand equation (1.6) and the supply relation (1.7). In both equations, the variable Z_t is called a demand rotator because the slope of the demand function changes with the value of Z_t when the value of α_3 is non-zero. The two equations reveal why the demand rotation identifies firm conduct. If there are no demand rotator or α_3 takes the value of zero, the supply relation changes to:

$$\begin{aligned} P_t &= -\lambda \frac{Q_t}{\alpha_1 + \alpha_3 Z} + \beta_0 + \beta_1 Q_t + \beta_2 W_t + \eta_t \\ &= -\lambda \frac{Q_t}{\alpha_1} + \beta_0 + \beta_1 Q_t + \beta_2 W_t + \eta_t \\ &= (\frac{-\lambda}{\alpha_1} + \beta_1) Q_t + \beta_0 + \beta_2 W_t + \eta_t. \end{aligned} \tag{1.8}$$

When $\alpha_3 = 0$, the supply equation does not include the variable Q_t^*, therefore only the composite term $\frac{-\lambda}{\alpha_1} + \beta_1$ is identified as the coefficient of Q_t employing equation (1.8). Therefore, the existence of a demand rotator is the key to the identification of the conduct parameter.

Berry and Haile (2014) extend the limited understanding of empirical IO literature for why data reveal firm conduct. Berry and Haile (2014) consider a setting where a heterogeneous product demand function derived from a random utility discrete choice model and heterogeneous firms is assumed. In their model, firms are heterogeneous in the sense that both the cost functions and their arguments vary depending on firms, and therefore the equilibrium production outputs are also different between firms. Therefore, the model of Berry and Haile (2014) is much more general than that of Bresnahan (1982).

Berry and Haile (2014, Theorem 8 on p.1777 and Theorem 9 on p.1782) shows that the oligopoly solution concept[19], which is utilized to recover marginal costs, is testable.[20] Berry and Haile (2014) point out the usefulness of variables which rotates "generalized marginal revenue" not "demand" function. The generalized marginal revenue is the function that is the solution of the first-order condition characterizing the equilibrium in an oligopoly model, see Berry and Haile (2014, Assumption 7a on p. 1766). Backus et al. (2021) reformulates the theorems of Berry and Haile (2014) as "under the true conduct assumption, recovered marginal cost shocks should not be correlated with those variables (rotaters of generalized marginal revenue) but under an incorrect conduct assumption

[19]It is firm conduct in this dissertation.

[20]The distinction between Theorems 8 and 9 in Berry and Haile (2014) is the assumptions that are imposed on cost functions or the availability of cost shifters that satisfy the condition called "index restriction". Theorem 8 needs the cost shifters which satisfy the index restriction but does not need additive separability of cost shock to cost functions, Theorem 9 is vise versa.

they will be."[21] The contribution of Berry and Haile (2014) is that the demand rotator is not the only variable used to identify firm conduct. Due to their contribution, empirical IO researchers now understand that much more variables can be used to identify firm conduct. The rotator of the generalized revenue function depends on the models considered. For example, in a differentiated products setting, the rotator includes the number of competing firms or goods, market size, characteristics of competing products, and other firms' cost shifters. Even the characteristics of own products can be the rotator in some situations.

Backus et al. (2021) and Duarte et al. (2020) propose to use GMM objective function which is constructed from excluded instruments, rotater of generalized revenue function but not cost shifters, in the Vuong-type model selection test based on Berry and Haile (2014)' s contribution. Chapter 3 of this dissertation is one of the few studies based on this new approach. In the empirical studies of Chapter 3, I rely on other firms' cost shifters as a rotator of the generalized revenue function.

1.2 Summary of later chapters

1.2.1 Deregulation and competition in Japanese intercity coach industry

In Chapter 2, I investigate the economic effects of deregulation in Japan's intercity coach industry. Specifically, I examine the intensity of competition in the industry using a unique dataset, to evaluate the economic effects of two major deregulations in 2002 and 2013. The absence of organized data means there is no previous researches that quantitatively evaluate the two deregulations. I collect data capturing the entry of bus operating companies by web-scraping and use a structural estimation method developed in econometrics for the purpose of measuring the degree of competition. The empirical analysis yields the following three main results. First, I find that the markup ratios always exceed 1, which indicates that the entry of one additional firm always intensifies competition. Specifically, the markup gained by one firm under duopoly is estimated to be about three-quarters of that under monopoly. Second, the competitive effect of an additional entry decreases as the number of incumbents increases. This result is obtained irrespective of the mode of competition. Third, I find that the services offered by firms in the industry are significantly differentiated. A counterfactual analysis reveals that additional 0.76 firms can enter a market on average by differentiating their products from each other. These results provide useful insights into the development of competition policy pertaining to the

[21] The word in the parenthesis is complemented by me.

contemporary transportation industry.

1.2.2 Inferece on noncooperative entry deterrence

In Chapter 3, I empirically investigate strategic entry-deterrence behavior under oligopolistic competition. To address this issue, I develop a structural econometric model based on the framework of Gilbert and Vives (1986), in which incumbent firms operating in an industry face the entry threat of a potential rival firm. In their model, incumbent firms deter entry by leaving the potential entrant only residual demand, which yields a profit short of the entry cost. I show theoretically that incumbents' marginal costs are interval-identified under the assumption that incumbents deter entry in equilibrium. The upper bounds of the marginal costs correspond to the costs at which the incumbents are indifferent between deterring or allowing entry, whereas the lower bounds correspond to the costs identified under the assumption of Cournot competition. The structural econometric model is estimated using data from an industry in which incumbents might have adopted an entry-deterring strategy, the Japanese aluminum smelting industry. A Vuong-type model selection test demonstrates that the model describing entry-deterrence behavior is more consistent with the data than is an ordinary Cournot competition model with the absence of entry threats. However, the explanatory power of the entry-deterrence model is lower than that of a perfect competition model.

Chapter 2

Deregulation and competition in Japanese intercity coach industry

2.1 Introduction

Japan's intercity coach industry has experienced two significant deregulations. The first deregulation was implemented in 2002. Before that, the Japanese Ministry of Land, Infrastructure, Transport, and Tourism (henceforth MLIT) had regulated free entry and exit. They had allowed only one firm to operate on a specific route; there were no competing rival firms on the route for an operator. Not only were entry and exit regulated, but fares were also simultaneously regulated to prevent firms from setting monopoly prices. In 2002, however, freedom of entry and exit were introduced and firms were permitted to set fares below the price caps set by the regulator. However, firms could not change their fares across time freely. In 2013, a new regime introduced within the intercity coach industry enabled firms to set their fares dynamically. The main purpose of this study is to evaluate the economic effects of these deregulations by focusing on the intensity of competition in the industry at present.

Transportation industries, including the intercity coach industry, have traditionally been regulated in many advanced countries and gradually deregulated in recent decades. In particular, Japan's bus industry, including intercity coaches and local buses, has experienced significant deregulation. Several studies have examined the economic consequences of the deregulation. Sakai and Takahashi (2013) reviewed the structure of the Japanese bus industry until the 1990s and the main features of the deregulation policy implemented in 2002, and then examined the consequences of the deregulation from three different perspectives: market structure, fares, and cost-efficiency. They concluded that there was

little change in market structure in the industry, even though the number of firms had doubled by 2006, mainly because of the formal recognition of small bus companies and the demerger of incumbent firms. They also identified fare discounting by incumbents following deregulation in some markets. The main objective of their study was to examine the effect of deregulation on cost efficiency rather than on competition. They found that deregulation had no significant effect on cost efficiency using the data of a publicly-owned firm. Because no studies have quantitatively evaluated the effect of deregulation on competitiveness, this study examines the intensity of competition among bus firms in Japan.

One reason why no quantitative researches exist in the literature is the lack of data. MLIT only reports macro-level measures; for example, it only reports the total number of operating bus firms in Japan and the total number of buses owned by all the operating firms. Hence, it is difficult to identify the entry behavior of individual firms. Therefore, I first construct market-level entry data that describe how many firms enter a market by collecting micro-level data. These micro-level data provide me with information regarding the route established by each firm. These data are collected by web-scraping, which is a technique of extracting patterned text from web pages on the Internet. I apply a structural estimation method developed in econometrics to the uniquely constructed dataset. This method is frequently used in empirical researches in industrial economics. Bresnahan and Reiss (1991a) developed the entry threshold ratio (ETR), which enables researchers to infer the nature of competition when market-level entry data are available. Because the transportation services provided in the intercity coach industry differ across firms, I also adopt a method developed by Schaumans and Verboven (2014). They demonstrated that the ETR is invalid for measuring the competitiveness of a market with differentiated products or services under several circumstances, and proposed an alternative measure called the adjusted ETR in Schaumans and Verboven (2014) that controls for product differentiation when additional data, such as market-level demand or revenue, are available. In my application, the adjusted ETR corresponds to the markup ratio, which measures the effect of entry of one additional firm on the markup of operating firms.

There are three major results from this study. First, the markup ratios are always estimated to exceed 1, suggesting that an additional entrant always intensifies competition. Specifically, the markup earned by one firm under duopoly is approximately three-quarters of that under monopoly. Second, the estimates based on Schaumans and Verboven (2014) model suggest that the effect of an additional entry on markup decreases as the number of incumbents increases, which is consistent with the prediction from industrial economic theory. These results are derived irrespective of the mode of compe-

tition, i.e., Cournot or Bertrand. Third, I find that the services of the Japanese intercity coach industry are highly differentiated. Specifically, I conduct a counterfactual analysis, revealing that product differentiation enables an additional 0.76 firms to enter a market on average. These results provide useful insights into the development of competition policy in the contemporary transportation industry.

Related literature

This study contributes to the existing literature in several ways. Fageda and Sansano (2018) stated that interurban bus, particularly regarding competition and the effects of liberalization, has not been widely studied. I contribute to the literature by studying the intercity coach industry, focusing on the effects of deregulation on the competitiveness of the industry. I focus on these effects for the following reason.

The performance of bus services, especially on local bus services, was studied extensively in the literature. The literature revealed that the presence of competition is one of the important determinants of the cost efficiency of local bus services (Augustin and Walter, 2010; Scheffler et al., 2013; Filippini et al., 2015). Therefore, I first analyze the competitive effect of deregulation.

This study is closely related to Dürr and Hüschelrath (2018), who studied the economic consequences of deregulation in Germany's interurban bus industry in 2013. They used a comprehensive route-level dataset, including information about when and which firms began to provide bus services on a specific route. Their dataset is similar to that of this study. They identified the determinants of the entry behaviors of potential entrants using a survival model. Their study differs from this study, however, because they did not focus on whether deregulation made the industry competitive. A number of other studies explored the economic impacts of deregulation. Tauchen et al. (1983) focused on the US intercity bus industry and estimated a multi-product cost function to assess the effects of the changes in the regulatory scheme. Dürr et al. (2016) investigated the competitive interaction between two large entrants after the deregulation in Germany in 2013. Blayac and Bougette (2017) studied the liberalization of the long-distance bus industry in France in 2015. Robbins and White (1986) reviewed the deregulation of the express coach industry in Britain in 1980, and the long-term effect of the deregulation in this industry is studied in White and Robbins (2012). An overview of the bus industry in Britain including recent regulatory changes in 2017 is outlined in White (2018)[1], who also points out a potential positive effect of the changes on bus use.

[1]White (2018), however, mainly focused on local bus industry in Britain.

Second, this study contributes to the literature by investigating the role of product differentiation. Mazzeo (2002a,b) introduced product differentiation into the entry game developed by Bresnahan and Reiss (1991a,b) and estimated the model using entry data of the motel industry. Seim (2006) adopted a counterfactual analysis to estimate the effect of product differentiation on the number of firms that can exist in a market. The counterfactual analysis in this study is similar to that in Seim (2006). As noted above, Schaumans and Verboven (2014) developed an entry model that controls for product differentiation and proposed it for the measurement of the nature of competition in a market with differentiated products.

The remainder of this chapter is organized as follows. Section 2.2 provides an overview of the Japanese intercity coach industry and the two significant deregulations implemented in the industry. Section 2.3 describes a theoretical setting and then presents two empirical models and an estimation strategy. In Section 2.4, I first describe the dataset and its sources, including entry data which were collected by web-scraping, and then derive the empirical results. The empirical results consist of two parts: parameter estimates and a counterfactual analysis. The counterfactual analysis reveals the effect of product differentiation on the number of firms that can exist in a market. Section 2.5 concludes the chapter by summarizing the main results and identifying topics for future research.

2.2 Industry

In this section, I review the history and laws of the Japanese intercity coach industry. Throughout this study, I refer to intercity coaches as bus services, which mainly drive along expressways and travel farther than 50 km. As I discuss in more detail later, because the laws and institutions of the Japanese bus industry were not established for long-distance transportation services until 2013, the history of the intercity coach industry is somewhat complex.

Japanese laws categorize bus companies into two types: fixed-route bus companies and chartered bus companies. Fixed-route bus companies are allowed to provide both local bus and intercity coach services. Intercity coaches, which are provided by fixed-route bus companies, have fixed routes and schedules like a local bus. Chartered bus companies provide transportation services by request only and do not provide intercity passenger transport services. However, chartered bus companies started to provide intercity transport services following the deregulation in 2002. For example, they provided intercity transport services in group package tours, which did not include sightseeing or lodging, but rather only passenger transportation. This type of intercity coach was called

an express tour bus.[2] Therefore, there coexisted two types of bus companies that provided intercity passenger transport services from 2002 to 2013.

Because chartered bus companies were not regulated by the laws related to fixed-route bus companies, they could freely provide intercity transport services. They could freely change schedules, fares, and routes daily through their websites. It, however, was said that express tour buses were unsafe compared with intercity transport services provided by fixed-route bus companies.

A serious accident resulting in the death of a number of people occurred in 2012. The accident forced the Japanese government to change industry laws in 2013, including the prohibition of chartered bus companies providing intercity transport services, such as express tour buses. The new laws relating to fixed-route buses are designed to take advantage of the flexibility of express tour buses. I review the history of the industry in the following subsection and then discuss the current state of the industry.

2.2.1 The history

The deregulation of the fixed-route bus industry occurred in 2002. The main purpose of the deregulation was the abolition of regulation called demand and supply balancing (DSB). The DSB consists of entry/exit and pricing regulations. The regulator at that time was concerned that excessive competition resulted in unsafe transport services and firms withdrawing from unprofitable routes or markets. The regulator aimed to satisfy demand on less profitable routes by forcing operating firms to cross-subsidize such routes. The regulator provided an exclusive right of operation to only one firm per route, enforced regulated fares leading to a normal profit, and prohibited the abolition of a route. While the DSB system guaranteed stable and safe transport services, this system did not promote competition among firms. Finally, the DSB was abolished in 2002.

The deregulation in 2002 removed all entry and exit restrictions. Specifically, when a bus company wants to enter a market, permission from the regulator is sufficient. The new entry system called comprehensive business permission enables entrants to operate all possible routes in Japan once their business has received permission to operate. To obtain permission, entrants must submit a business plan that includes operation schedules, routes, and fares to the regulator and must prove their ability to provide stable transport services. Exit from routes was permitted in the deregulation in 2002, whereas it had been

[2]Even though chartered bus companies were not assumed to provide intercity transport services in the laws, they had provided services until 2013. Because chartered bus companies cannot provide these services voluntarily, a travel agency must charter a bus from a chartered bus company first. The agency then sells seats on the bus as a travel commodity or package tour that does not include any sightseeing or lodging.

completely prohibited before that time. If a firm wanted to abolish a route, the firm only needed to report this intention to a regional transport bureau six months before an exit. After exiting a route, however, firms were not allowed to re-enter the route for one year. Fixed-route bus companies also became capable of price-setting below a maximal price cap; price regulation became price-ceiling regulation.

At the time of deregulation in 2002, a new type of business called express tour buses began to emerge. An express tour bus is a package tour provided by chartered bus companies, which does not include sightseeing or lodging but only provides transport services. Because express tour buses were not regulated by the laws relating to fixed-route bus companies, chartered bus companies could provide passenger transport services more flexibly than fixed-route bus companies. There are three main differences in the business formats between intercity transport services provided by chartered bus companies (express tour buses) and those provided by fixed-route bus companies.

First, as mentioned above, entry to and exit from a route imposes costs on fixed-route bus companies. In contrast, chartered bus companies need not submit a notification to a regional transport bureau before entering a new route. Second, chartered bus companies could adjust prices flexibly. Chartered bus companies operating express tour buses could set fares per trip or seat rather than per route. They could also change their fares daily. In contrast, fixed-route bus companies must set fares for each route. Moreover, if they intended to change their fares, they had to report their intention to a regional transport bureau one month before the change. Third, there was a difference between the two whether a company has to establish bus stops. Because express tour buses operate as chartered buses, chartered bus companies did not need to establish bus stops. Instead, they used streets or parking lots as bus stops. Fixed-route bus companies must provide bus stops for their routes.

In the past, express tour buses were viewed as being unsafe compared with intercity transport services provided by fixed-route bus companies that operate under strict safety standards.[3] Because both laws regulating fixed-route bus companies and chartered bus companies did not consider the business model of express tour buses, the regulatory authority which considered it a problem began to explore an effective regulatory scheme for the intercity coach industry. From 2010 to 2012, the regulatory review that considers the regulation scheme of the intercity coach industry called "ideal bus business review"was held 12 times by MLIT. In these reviews, the ban on express tour buses was implemented,

[3]Although there is no direct evidence that the express tour bus was more dangerous than intercity transport service by fixed-route bus companies, such as accident rate, the public perception that the express tour bus was dangerous might spread because many media reported accidents caused by express tour bus.

and the chartered bus companies that had operated express tour buses now required permission as a fixed-route bus company to continue providing intercity transport services. The final five of these reviews were held as a result of an accident causing the death of several people by an express tour bus in 2012. In response to the accident, the attendees at the reviews decided that the operational safety of transport services is the most important consideration for regulation and that the period over which chartered bus companies operating express tour buses can convert into a fixed-route bus company to continue operating an intercity transport service was decreased from two years to one year because express tour buses were considered to be unsafe. In addition, to ensure a smooth transition to the new scheme, it was decided in these reviews that regional transport bureaus would help chartered bus companies provide bus stops. Since August 2013, only fixed-route bus companies have been allowed to provide intercity transport bus services. In these regulatory reviews, the new intercity coach system was developed in a way that incorporates several advantages of express tour buses

2.2.2 Current industry

The new intercity coach system from 2013 has three main objectives: (a) transition of chartered bus companies operating express tour buses to fixed-route bus companies, (b) flexible supply balancing and fare setting, and (c) safety enhancement. Point (a) means that all the entrants are fixed-route bus companies, point (b) enables dynamic pricing or revenue management, and point (c) involves changes, such as the maximum continuous driving distance being decreased from 670 km to 400 km at night and 500 km during the day. With regard to the modeling assumptions I will discuss in Section 2.3, points (a) and (b) are important, since point (a) guarantees that all the potential entrants face the same entry condition and are homogenous and point (b) guarantees no price restrictions and free competition.

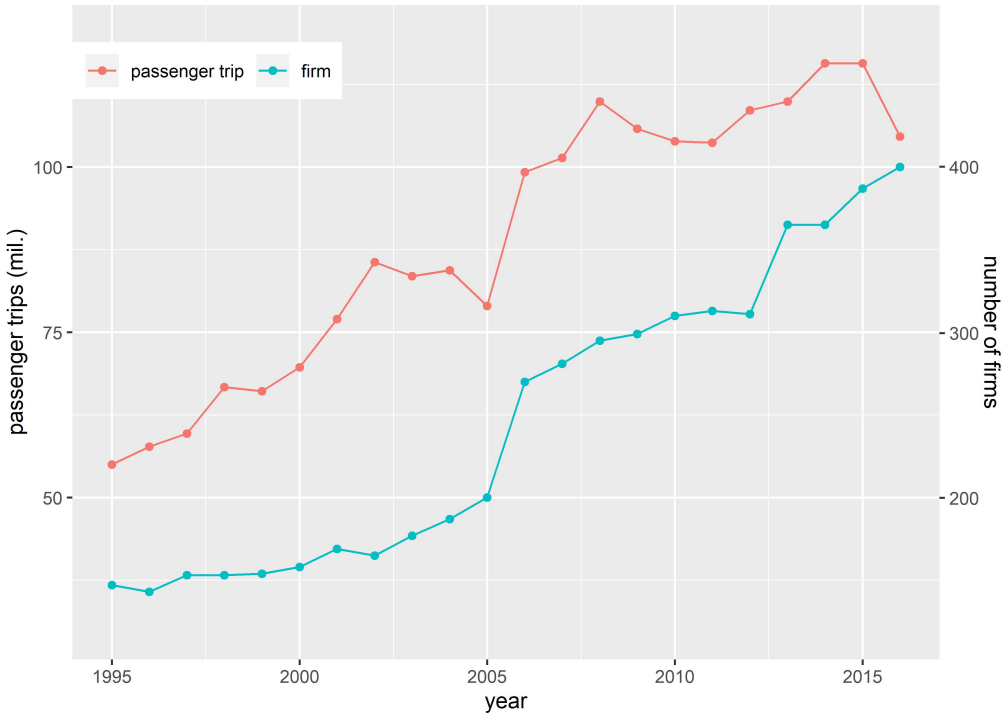
It is also important that a framework called "80% wide fares"was introduced at the same time. This framework requires a fixed-route bus company to set a maximal fare for a route, which then enables the firm to change the fare within the range of the maximal fare and 80% of that fare without declaring the change. This maximal fare can be applied more than once and bus companies can select arbitrarily among such maximal prices.[4] This scheme has allowed bus companies to have fare-setting flexibility, i.e. dynamic pricing or revenue management can also be adopted.

[4]In the system of "80% wide fares", a fixed-route bus company can apply multiple maximal fares under price cap set by the regulator. To apply these maximal fares finely, the company can change their fare without daily declarations under the price cap set by the regulator.

As I have mentioned above, entry and exit conditions were also changed in 2002, and the same conditions have remained unchanged. Namely, a fixed-route bus company can exit a route by submitting a notification six months before an exit, and entry is allowed as long as the transportation service provided by a bus company is safe and sustainable.

The above overview of the history of the bus service industry suggests that the current intercity coach market is subject to free competition. Before setting up the model to examine the nature of competition within the industry, I review some macro measures.

Figure 2.1: Trends in the number of operating firms and the patronage

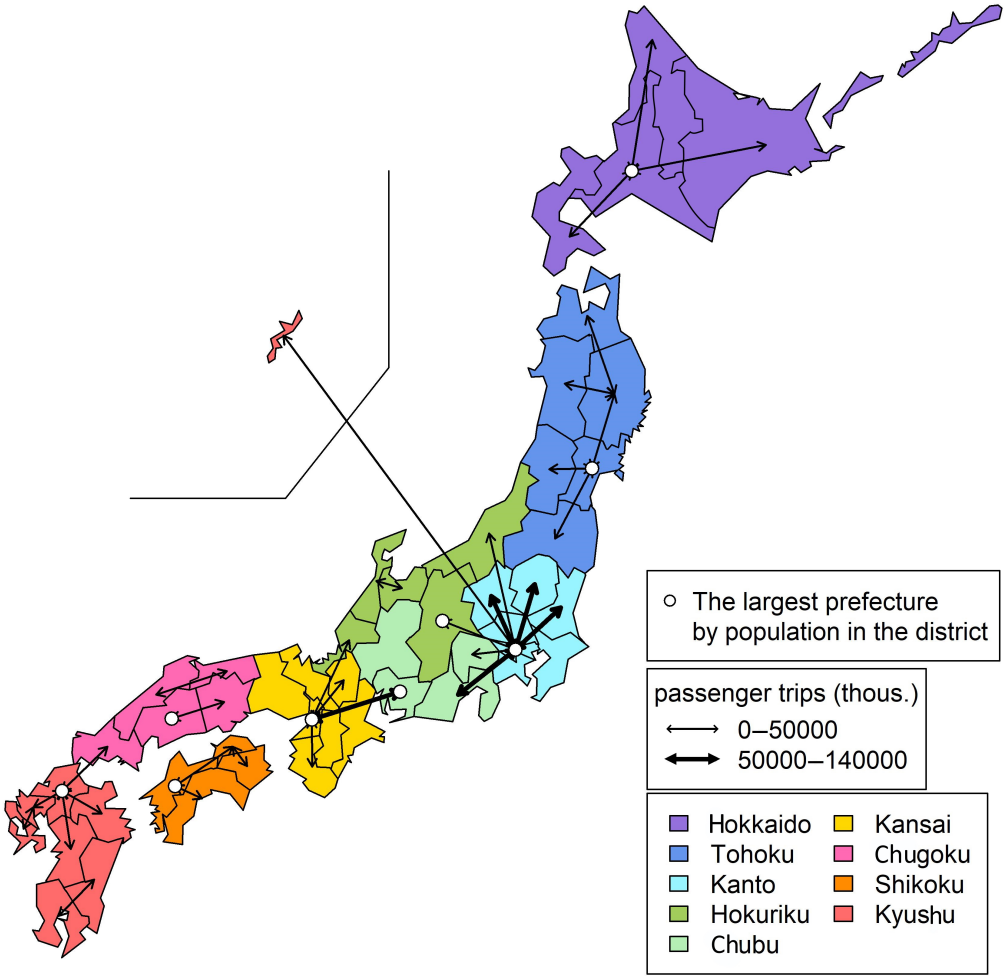


Source: Japanese Bus Association (2016)

Figure 2.1 shows the trends of the numbers of operating companies and the patronage in the industry. After the deregulation of 2002, the number of operating companies had doubled by 2016.[5] Similarly, the patronage also grew after the deregulation and the

[5]As Sakai and Takahashi (2013) point out, the increase in the number of operating firms includes the demergers of incumbents. Fixed-route bus companies employed demergers as a means of cost reduction. The mechanism through which demerger leads to cost reduction was explored in the literature (Takahashi, 2004; Sakai and Suzuki, 2011). Japanese fixed-route bus companies experience difficulties in making changes to workers' salaries or wages. Suppose that a bus company operates services in several regions and the company manager wants to cut off the wages of employees in a specific region. If the manager could change the wages of workers in only that region, there would have been no problem. However, if the wage schedule is specified at the entire firm level and the manager thus cannot vary wages regionally, the company has an incentive to demerge the business in the region. In this case, the company is likely to demerge its regional services as a separate company and construct a new wage schedule for the new company that is more

Figure 2.2: Principal inter-prefectural movements in the long-distance travel market



Source: Inter regional travel survey in Japan 2015 (MLIT, 2015).

growth rate of the passenger trips seems to be modest in recent years. With regard to the market size, about 115 million passenger trips were made by intercity coaches in 2015.

Not only an intercity coach but also other modes of transportation play a role in the long-distance travel market. Table 2.1 describes the modal share in 2015 and the number of passenger trips by travel distance bands. I report the patronage in parenthesis. Although rail plays a most important role in the long-distance travel market among the various modes of public transportation, intercity coaches also play a role for almost all travel distance bands. In contrast, airlines are mainly used for very long-distance travel. Overall, the share of intercity coaches is 2.5% in the long-distance travel market (see the last row of Table 2.1).

Figure 2.2 illustrates the major inter-prefectural passenger movements occurring for long-distance travel by entire transport modes. In the figure, I connect two prefectures with a line if the patronage between the two prefectures is the largest for either of the two prefectures. More specifically, I first fix one prefecture and then connect it with its counterpart prefecture which has the largest patronage between the fixed prefecture among the other prefectures.[6] In the figure, the 9 districts consisting of Japan are separated by color and the prefectures which have the largest population in their district are marked with circles. The figure shows that the passenger flows between the major prefecture in a district and the other prefectures in the same district are relatively large. Second, the flow to the three metropolitan areas, Tokyo, Osaka, and Aichi is also large.

2.3 Model

2.3.1 Theoretical setting

The theoretical models in this study closely follow those of Bresnahan and Reiss (1991a) and Schaumans and Verboven (2014). In this section, I first set up a game-theoretic model and propose a measure of the nature of competition derived from the models. Specifically, I consider a two-stage entry game, in which there are a number of potential and homogeneous entrants as players. At the first stage, each of the firms decides whether or not to enter a market based on the future profit they will earn. At the second stage,

regionally appropriate.

[6]In the figure, there exist prefectures that are not connected with any other prefectures. This is because I combine some prefectures and regard the combined area as a prefecture. More specifically, Tokyo and its surrounding prefectures, Osaka and its surrounding prefectures, and Aichi and its surrounding prefectures are combined. The three prefectures of Tokyo, Osaka, and Aichi are major metropolitan areas in Japan. In contrast, Hokkaido prefecture, which has the largest land area and is in the northeast of Japan is divided into four blocks and each of the four blocks is regarded as a prefecture.

Table 2.1: Modal share and patronage by travel distance bands in 2015

mode	airline	rail	ship	bus	car	all modes
unit	% (mil.)	% (mil.)	% (mil.)	% (mil.)	% (mil.)	% (mil.)
0–100 km	0.0 (0.0)	3.4 (12.3)	0.5 (2.1)	1.2 (4.3)	94.8 (340.6)	20.0 (359.2)
100–200 km	0.0 (0.4)	11.1 (88.9)	0.3 (2.0)	2.3 (18.2)	86.3 (692.5)	44.7 (802.1)
200–300 km	0.0 (0.0)	15.8 (34.6)	0.2 (0.4)	3.4 (7.5)	80.6 (176.8)	12.2 (219.3)
300–500 km	1.9 (4.0)	43.2 (92.2)	0.2 (0.4)	4.5 (9.5)	50.2 (107.1)	11.9 (213.2)
500–700 km	11.7 (10.7)	64.4 (58.9)	0.6 (0.5)	4.3 (3.9)	19.0 (17.4)	5.1 (91.5)
700–1000 km	42.8 (19.2)	42.5 (19.1)	0.1 (0.5)	3.0 (1.4)	10.6 (4.8)	2.5 (45.0)
1000–km	87.3 (55.1)	6.6 (4.2)	0.4 (0.3)	0.4 (0.2)	5.2 (3.3)	3.5 (63.1)
overall	5.0 (89.5)	17.3 (310.2)	0.3 (6.2)	2.5 (45.1)	74.9 (1,342.5)	100 (1,793.4)

Note: Source: Inter-Regional Travel Survey in Japan 2015 (MLIT, 2015). The modal share and the patronage by travel distance bands and modes are reported in each column. The unit of the share is percent (%), and that of the patronage is million passenger trips. Because the survey only focuses on trips beyond the borders of a prefecture, the overall bus patronage in Table 2.1 (about 45 mil.) and Figure 2.1 (about 115 mil.) is not the same. The last column represents the ratio of the patronage in each travel distance band to the overall patronage.

in which the number of market participants has already been fixed, they compete against each other and generate profits. I do not specify the mode of competition such as Cournot, Bertrand, or the other modes of competition.

Market outcomes, such as profit and welfare, are determined by the mode of competition, cost, and demand. I assume that marginal cost is c and that potential entrants incur fixed cost f if they decide to enter. Both c and f are positive constants.

I assume that there is a representative consumer in a market, namely, that the demand function of the market can be written as:

$$S \times Q(p, N), \tag{2.1}$$

where $Q(p, N)$ is the demand function of a representative consumer, S denotes the market size, such as population, and N represents the number of operating firms in a market. I, hereafter, call $Q(p, N)$ the per capita demand function. The argument N in the per capita demand function captures the possibility of product differentiation. I only allow for product differentiation in which the price and demand of each firm are identical in an equilibrium. I explain why argument N in the per capita demand function can capture product differentiation. Suppose that there is a possibility of product differentiation, then consumers increase their consumption as the number of firms N increases because the variety of products increases. In contrast, if there is no product differentiation, demand is not affected by the number of firms. Therefore, the per capita demand is increasing in the

number of operating firms: $\frac{\partial}{\partial N}Q(p,N) \geq 0$. The statement $\frac{\partial}{\partial N}Q(p,N) = 0$ corresponds to no product differentiation.

From the assumption of the existence of a representative consumer, per firm profits in the market with N operating firms can be expressed as:

$$\pi(N) = S \times v(N) - f \tag{2.2}$$

$$= S \times \mu(N)q(N) - f, \tag{2.3}$$

where $v(N) = (p(N) - c) \times q(N)$ is the per firm per capita variable profit in a market, and c and f represent variable and fixed cost, respectively. Furthermore, $p(N)$ is the equilibrium price in the second stage of the game, $q(N) = \frac{Q(p(N),N)}{N}$ is per firm per capita demand, and $\mu(N) = p(N) - c$ is the markup of firms.

Measure of the nature of competition

I define a measure of the nature of competition. By estimating this measure, we can study the following question: does an additional entry intensify competition? I introduce only the intuition of how to use the measure because formal presentations of the measure are provided in Bresnahan and Reiss (1991a); Schaumans and Verboven (2014); Berry and Tamer (2006).

The entry threshold is defined as the minimum market size necessary for N firms to profitably enter a market. The value is derived by solving the equation $S \times v(N) - f = 0$ for market size S.

$$S_N = \frac{f}{v(N)},\ N = 1, 2, 3, ... \tag{2.4}$$

$$s_N = \frac{S_N}{N},\ N = 1, 2, 3, ..., \tag{2.5}$$

where S_N is the entry threshold and s_N is the per firm entry threshold, which is the minimum market size per firm necessary for N firms to earn positive profits. The entry threshold ratio (henceforth ETR) is defined as the ratio of per firm entry threshold.

$$ETR(N) = \frac{s_N}{s_{N-1}},\ N = 2, 3, 4, ... \tag{2.6}$$

This is the measure of the nature of competition. If $ETR(N)$ is equal to 1, then an additional entry does not intensify the degree of market competition. If $ETR(N)$ is greater than 1, then an additional entry to the market that has $N - 1$ incumbents intensifies market competition.

I explain an intuition by comparing two modes of competition. Consider a market in which firms form a cartel. In a simple cartel, they cooperatively charge the monopoly price regardless of the number of firms operating in the market. They earn monopoly variable profit and divide the profit among the members. Recall that variable profit is proportional to market size and that in the first stage potential entrants enter the market if they expect to earn a positive profit after entry. Suppose that there is only one firm in a market; the firm is a monopolist, and suppose that the firm earns variable profit equal to fixed cost f for a given market size S. Therefore, the minimum market size necessary for one firm to profitably operate in the market is S, namely $S_1 = S$. Because doubling or tripling the market size results in the doubling or tripling of the monopolist's variable profit, if the competition mode is a cartel, $2S$ or $3S$ is sufficient for the market to enable 2 or 3 firms to operate in the market. This means that $S_2 = 2S,\ S_3 = 3S$, and $ETR(2) = ETR(3) = 1$ in a simple cartel.

In contrast to the above, consider the situation in which competition actually arises between firms and in which all the parameters except for the competition mode are the same as the above cartel situation. Therefore, in the same way as above, the minimal market size necessary for one firm to earn positive profit S_1 is equal to S. If there are two firms in the market, the sum of their variable profits should be lower than that of the cartel members because of the lower market equilibrium price, therefore doubling of the market size, namely to $2S$, is insufficient to support the two firms in the market. This means $S_2 > 2S$ and $ETR(2) \geq 1$. Furthermore, if a third entry increases competition which results in a lower equilibrium price, then the minimal market size for the three firms should be greater than three halves of that for two firms, namely $S_3 > \frac{3}{2}S_2$. This means that $ETR(3) \geq 1$ holds.

Although the intuition behind why $ETR(N)$ can be used for inferring the nature of competition is clear, Schaumans and Verboven (2014) proved that in a product differentiation setting, $ETR(N)$ can take a value less than 1, and that even in the case of $ETR(N) \leq 1$, there is a possibility that an additional entry of a firm intensifies competition. Because product differentiation expands demands, regardless of whether an additional entry actually intensifies competition, namely $\frac{\partial p(N)}{\partial N} < 0$, there is the possibility that $ETR(N)$ takes a value less than 1.[7] They propose an alternative measure to $ETR(N)$, which is suitable in a product differentiation setting, and reveal that it can be estimated when a researcher has additional data, such as market-level demand or revenue data. They call the measure the adjusted ETR, which is identical to the markup ratio $\frac{\mu(N-1)}{\mu(N)} = \frac{p(N-1)-c}{p(N)-c}$ when market-level demand data are used. Similar to $ETR(N)$, the measure takes a value greater than 1 in a

[7] $ETR(N) \geq 1$ always suggests that an additional entry leads to intensified competition.

competitive environment. Additionally, this measure identifies how much an additional entry influences the markup.

2.3.2 Empirical model

I estimate two models in Section 2.4. One is a traditional entry model with one equation that endogenously determines the number of operating firms and the other is a simultaneous equation model in which the number of firms and equilibrium demand are simultaneously determined. I call the first BR or an ordered probit model because the model takes the form of a traditional ordered probit model whose threshold represents a change of profit among the number of firms. Meanwhile, I call the second SV or a simultaneous equation model. I assume a cross-sectional setting in both models; I assume that we can observe equilibrium outcomes and market conditions in many markets.

BR model

First, I consider the situation in which we only observe the number of firms N as a market equilibrium outcome. The condition that there exists just N firms in a market is as follows.

$$\log \frac{v(N+1)}{f} + \log S < 0 < \log \frac{v(N)}{f} + \log S \tag{2.7}$$

I call equation (2.7) the free entry condition.[8] To capture heterogeneity among markets, I specify the log of the ratio of variable profit to fixed cost as:

$$\log \frac{v(N)}{f} = X\lambda + \theta_N - \omega, \tag{2.8}$$

where the parameter θ_N is the coefficient of the dummy variable of the number of firms and is decreasing in N because of intensified competition or splitting of the profit among all market participants even in the case of a cartel. The variables X, which do not include an intercept, are the observable market demographics that affect demand, variable cost, and fixed cost, and λ are the corresponding parameters. The effects of unobservable factors on variable profit and fixed cost or measurement errors are captured by ω. Substituting equation (2.8) into equation (2.7) yields:

$$X\lambda + \theta_{N+1} + \log S < \omega < X\lambda + \theta_N + \log S.$$

[8]The free entry condition represented as equation (2.7) is restated as $v(N+1)S - f < 0 < v(N)S - f$. If we observe that no firm exists in a market, the condition is stated as: $\log \frac{v(1)}{f} + \log S < 0$.

By making a distributional assumption on ω, such as a normal distribution or logistic distribution, we obtain the likelihood of observing just N firms, enabling maximum likelihood estimation of the parameters as an estimation strategy. I assume a normal distribution, namely,

$$\omega \sim N(0, \sigma_\omega^2).$$

The entry threshold and ETRs are estimated as follows.

$$S_N = \exp(-\log \frac{v(N)}{f}) = \exp(-X\lambda - \theta_N),\ N \in \{1, 2, 3, ...\},$$
$$ETR(N) = \exp(\theta_{N-1} - \theta_N)\frac{N-1}{N},\ N \in \{2, 3, 4, ...\}. \tag{2.9}$$

SV model

Consider the situation in which we can observe the equilibrium market demand and the number of firms as market outcomes. To embed the demand data in a model, I exploit the representation of variable profit in equation (2.3). The free entry condition can be written as:

$$\log \frac{\mu(N+1)}{f} + \log q(N+1) + \log S < 0 < \log \frac{\mu(N)}{f} + \log q(N) + \log S. \tag{2.10}$$

I separately specify the logarithm of the ratio of markup to fixed cost and the logarithm of per firm per capita demand such as:

$$\log \frac{\mu(N)}{f} = X\gamma + \delta_N - \eta, \tag{2.11}$$
$$\log q(N) = \beta_0 + X\beta + \alpha \log N + \xi, \tag{2.12}$$

where δ_N is the parameter that captures the competitive effect of market structure on markup and is decreasing in N because of intensified competition. The effects of market demographics X on the logarithm of the ratio of markup to fixed cost and on the per firm per capita demand are captured by γ and β, respectively. Because the interpretation of the unknown parameter α requires a caution, I defer the explanation of the parameter until later. The unobservable factors that affect markup or fixed cost and demand are captured by η and ξ, respectively. Substituting equations (2.11) and (2.12) into equation

(2.10) yields:

$$X(\beta+\gamma)+(\alpha\log(N+1)+\delta_{N+1}+\beta_0)+\log S < \eta-\xi < X(\beta+\gamma)+(\alpha\log(N)+\delta_N+\beta_0)+\log S. \tag{2.13}$$

Rearranging equation (2.13) gives:

$$X\lambda + \theta_{N+1} + \log S < \omega < X\lambda + \theta_N + \log S. \tag{2.14}$$

where $\omega = \eta - \xi, \lambda = \beta + \gamma$, and $\theta_N = \alpha \log N + \delta_N + \beta_0$. To estimate the parameters by maximum likelihood estimation, the distribution of error terms has to be specified. I assume a bivariate normal distribution that has an unrestricted covariance and variance parameter, namely,

$$\begin{pmatrix} \omega \\ \xi \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\omega^2 & \sigma_{\omega\xi} \\ \sigma_{\omega\xi} & \sigma_\xi^2 \end{pmatrix}\right).$$

See Schaumans and Verboven (2014) for the precise form of the likelihood function of observing equilibrium outcome (N, q) conditional on market demographics X. Because I assume a normal distribution, a two-step type estimation procedure, such as Heckman (1974), can be used.[9] Once we obtain the model parameter estimates, the markup ratio $\frac{\mu(N-1)}{\mu(N)}$ and the ETR are esitmated as follows.

$$\text{Markup\_Ratio}(N) = \exp(\delta_{N-1} - \delta_N),\ N \in \{2, 3, 4, ...\} \tag{2.15}$$

$$ETR(N) = \exp(\delta_{N-1} - \delta_N) \times (\frac{N-1}{N})^{1-\alpha},\ N \in \{2, 3, 4, ...\} \tag{2.16}$$

Next, let me consider the interpretation of α. I interpret the parameter α as the degree of product differentiation. For example, I interpret the estimate of $\hat{\alpha} = -0.4$ as a high degree of product differentiation. From equation (2.12), α is the derivative of the log of per firm per capita demand $\log q$ with respect to the log of the number of operating firms in a market: $\alpha = \frac{d\log q(p(N),N)}{d\log N}$. I can decompose the effect of the number of operating firms on demand such as:[10]

$$\begin{aligned} \alpha &= \frac{dq(p(N),N)}{dN}\frac{N}{q} \\ &= (q_p p'\frac{N}{q}) + (q_N\frac{N}{q}). \end{aligned} \tag{2.17}$$

[9] Mazzeo (2002a) adopt a two-step type estimation strategy to examine data including price and entry.

[10] q_p and q_N denote the derivatives of the per firm demand function with respect to price and number of firms, and p' is the partial derivative of equilibrium price relative to number of firms.

From equation (2.17), we can observe that the parameter α captures a direct effect and an indirect effect of the number of operating firms on demand. The indirect effect is the effect on demand through a decreased equilibrium price and is captured by the first term in equation (2.17), and the direct effect occurs through the second term in equation (2.17). The second term is the elasticity of demand concerning the number of operating firms.

The market expansion effect caused by product differentiation is captured through this term. When there is no room for product differentiation, entry of one additional firm into a market does not lead to demand increase: $\frac{\partial Q(p,N)}{\partial N} = 0$. Moreover, the per firm per capita demand q decreases significantly because many firms divide the fixed market demand. In this case, the elasticity of demand to the number of operating firms in equation (2.17) takes the value of -1 because $\frac{\partial Q(p,N)}{\partial N} = 0$ means that $q + q_N N = 0 \Leftrightarrow q_N \frac{N}{q} = -1$.

On the other hand, when the firms can enter with a differentiated product or service, a market expansion effect arises: people who have not previously bought the products in the market would start buying the new product or service. Because of this effect, per firm per capita demand q in equation (2.12) does not decrease much even though the number of operating firms N increases. In this case, the elasticity of demand in equation (2.17) takes a value larger than -1. For the extreme, where the operating firms provide independent products, an additional entry does not affect the incumbents' demand conditional on the price being unchanged, i.e. $q_N = 0$. In this case, the elasticity of demand to the number of operating firms takes the value of 0. Therefore, the second term in equation (2.17) takes a value between -1 and 0.

The first term is the indirect effect of the number of operating firms on equilibrium per firm per capita demand through a decreased price and takes a positive value because of the assumption of $q_p < 0$ (or equivalently, $Q_p < 0$) and $p' \leq 0$. If the first term takes a modest value, we can interpret α as being the degree of product differentiation. Moreover, we can interpret the value of $1 + \alpha$ as the market expansion effect arising from product differentiation.[11]

[11] I interpret $1+\alpha$ as the market expansion effect arising from product differentiation because the elasticity of market demand to the number of operating firms $\frac{\partial Q(p,N)}{\partial N}\frac{N}{Q}$ is equal to $1 + \alpha$ under the assumption that the first term in (2.17) is zero.

2.4 Empirical analysis

2.4.1 Data and market definition

To estimate the model parameters, entry threshold, and markup ratio, I need data on the number of operating firms, market demand, and market demographics. There are several sources from which I obtain data.

Number of operating firms in a market

I first construct a micro-level dataset that provides me with information concerning the route by which each firm entered a market using web-scraping. The data come from the website called "bus hikaku navi", which is the most widely used site for making a reservation on intercity coach services in Japan [`https://www.bushikaku.net/`]. The site provides trip-level[12] information about intercity coaches, including origin, destination, time, and operator name. On the website, when we take a bus reservation using the site, we are required to select an origin and destination at the prefecture level and a departure time at the date level. For example, the site presents many bus trips for the input [Tokyo → Osaka, August 26, 2018]. Tokyo and Osaka are both prefectures in Japan. I extracted all the bus trips that can be reserved from this site and constructed a dataset with each record representing one trip. Each record includes information on time, bus stops, and the name of operating firms. I collected the trip information for August 26, 2018, on August 19, 2018. The data indicate that we could have reserved 12,025 trips at that time.[13] I can confirm from a survey by MLIT that 15,756 trips are provided by the entire fixed-route bus companies in Japan per day. As mentioned above, 12,025 trips were operated by 175 fixed-route bus companies on August 26, 2018. This site covers most of the intercity coach transport services in Japan.[14]

I need data at the market level to estimate the models. In particular, I need the number of operating firms in a market. To aggregate the trip-level dataset, which I collect by

[12]Trip level means any bus trips that can be reserved in the site.

[13]The web-scraping procedure is as follows. The website provides information if we enter the origin and destination prefectures and departure date into a box shown on the site. Once we enter this information, the site presents all the trips that can be reserved. Because there are 50 prefectures in Japan, I searched for bus trips 50×49 times. There is a possibility that one bus trip is scraped or seen in several searches because some bus trips connect more than two prefectures. After excluding such duplications, there were 12,025 possible trips on that day.

[14]The number of operating firms in the industry identified through the data collection procedure is smaller than the number reported by MLIT in Figure 2.1. This is because of joint operations. Although some of the routes are operated by more than one firm, the information on the site displays one trip as being operated by only one firm.

web-scraping, into market-level data, I first have to define a market.

I define a market as a nondirectional combination of two prefectures. For example, the combination of Tokyo and Osaka is regarded as a market in this study, and it is denoted as (Tokyo, Osaka).[15] Because the area of some prefectures in Japan is particularly large, there are intercity coaches that connect two cities in one prefecture, which are observed in the data. By definition, these intra-prefectural markets are excluded from the sample.[16] Because there are 50[17] prefectures in Japan, there are ${}_{50}C_2 = 1225$ potential markets. Because I exclude some of the markets, there are finally 926 markets that are the object of the following empirical analysis.[18]

Using the trip-level dataset and the market definition, I construct the market-level variable of the number of firms in a market as follows. Although the number of trips per day provided by an operating firm in a market is heterogeneous among the operators in the market, I assume that a company enters a market if the company offers at least one trip in the market. Namely, whether the firm offers multiple trips or a single trip per day, I assume that the firm entered the market once; I ignore the scale of operation in the market. If a firm operates a route crossing more than two prefectures, the firm is considered to enter not one but multiple markets. For example, suppose that a firm operates a coach that departs from Tokyo, first stops in Kyoto, and then stops in Osaka. I then assume that

[15]Even if I denote the market (Tokyo, Osaka) as (Osaka, Tokyo), it represents the same market because I define a market as a combination of two prefectures; I do not define a market as a directional pair of two prefectures.

[16]Any airport market is not treated as an observation in the sample while airport market developments after deregulation were reported and express coach tends to serve the link successfully in several European countries (van de Velde, 2013). Adachi (2005) explore airport services to Haneda. Located in the southern part of the Tokyo metropolitan area, Haneda Airport is the largest airport in Japan. The airport market developed in the late 1990s because of an increase in airport users and highway extension and inter-prefectural direct coach services that cover the surrounding prefectures of the airport have been provided. Adachi (2005) details the expansion process of the direct services from/to Haneda Airport. His work concludes that the development is not related to the deregulation in 2002, which differs from the case of Britain or other European countries. In the study, he interviewed the operators that entered the market after the deregulation and asked their motivation or backgrounds of their entry and the operators stated that there was no relationship between their entry and the deregulation.

[17]As I note on footnote 13, Hokkaido prefecture is divided into 4 blocks, and each block is regarded as a prefecture. Therefore, the number of prefectures is 50.

[18]I exclude the markets which satisfy any one of the following three conditions. First, I exclude the markets in which the distance between two prefectures is too far or the two prefectures are separate islands. Second, as I mention below, I combined the constructed data on the number of operating firms and the market-level demand data from MLIT. Therefore, I exclude the markets that are inconsistent in these numbers of firms and demand; markets in which the demand is positive but the number of operating firms is zero or the demand is zero but the number of operating firms is positive. Third, I also exclude the markets whose component two prefectures are both in Kanto or Kansai districts and are adjacent to each other. This is because the values of the JR variable, which I employ in the empirical analysis and is mentioned afterward, may include short-distance travel in the market meeting the third condition. Therefore, the final sample size is 926 rather than 1225.

the firm entered the two markets: (Tokyo, Kyoto) and (Tokyo, Osaka). This firm is not regarded as entering the (Kyoto, Osaka) market if the trip did not appear during the search of [Kyoto →Osaka] or [Osaka → Kyoto]. I calculate the number of operating firms in a market by counting the entry behavior defined above. Table 2.2 reports the distribution of the number of operating firms in a market. I aggregate the number of markets that have 10 or more and 19 or fewer firms in the table. In the same way, I aggregate the number of markets that have 20 or more and 24 or fewer firms. From the table, there are a substantial number of monopoly markets. There exist 24 and 22 firms in the (Tokyo, Osaka) and (Tokyo, Kyoto) markets, respectively.

Table 2.2: Distribution of the number of operating firms in a market

number of firms	0	1	2	3	4	5	6	7	8	9	10–19	20–24
number of markets	638	100	65	40	26	15	12	8	6	3	11	2

Note: The number of observations, which is the number of markets is 926. I aggregate the number of markets that have 10 or more and 19 or fewer operating firms. In the same way, I aggregate the number of markets that have 20 or more and 24 or fewer firms.

Demand data

The demand data used in the analysis come from passenger area flow statistics[19] (Ryokaku Chiki Ryudo Chosa, in Japanese) published by MLIT. The statistics report the number of passenger trips for each directional pair of two prefectures each year. In other words, the statistics report the number of passenger trips made from one prefecture to another per year by intercity coaches. MLIT requires all the fixed-route bus companies to report the number of passenger trips they transported per route and directional pairs of prefectures. The statistics are compiled from the reports submitted by each firm. I calculate the market-level demand variable Q by taking the mean of the two-directional number of passenger trips.[20] Because I assume the existence of a representative consumer, per firm per capita demand q is calculated as: $q = \frac{Q}{N \times \text{population}}$.

[19]The data I employ in the empirical analysis, called 'Ryokaku Chiki Ryudo Chosa'in Japanese, is not the same as the data that the Inter-Regional Travel Survey employed to report Table 2.1. This is the reason why the statistics I employ in the empirical analysis suggest that the overall passenger trips between two prefectures by intercity coaches in the sample is 55 million, while the Inter-Regional Travel Survey reports it as about 45 million as in Table 2.1.

[20]A market consists of two prefectures, e.g. (Tokyo, Osaka). The demand data reported in the passenger area flow statistics have direction. For example, regarding the (Tokyo, Osaka) market, the statistics report the number of passenger trips moving from Tokyo to Osaka ($Q_{\text{Tokyo}\to\text{Osaka}}$) and moving from Osaka to Tokyo ($Q_{\text{Osaka}\to\text{Tokyo}}$). I calculate the demand in the (Tokyo, Osaka) market as the mean of such a two-directional number of passenger trips: $Q_{(\text{Tokyo,Osaka})} = \frac{1}{2} \times (Q_{\text{Tokyo}\to\text{Osaka}} + Q_{\text{Osaka}\to\text{Tokyo}})$.

Demographics

I use the demographic variables described in Table 2.3. These variables are employed to capture the heterogeneities in market conditions among the markets.

The demographic composition of a market is expected to affect the demand for intercity coach travel. For example, MLIT (2015) revealed that young people tend to use intercity coaches rather than rail[21]; to capture this information, I use two demographic variables: the average income per capita in a prefecture and the ratio of the number of high schools and undergraduate students to the overall population in a prefecture. The lodge variable, which is the total number of hotel guests in a prefecture, is employed to capture the general demand[22] for intercity coach travel. I expect the lodge variable to capture the demand that is derived from the purpose of sightseeing or business. In contrast, the JR variable, which is the total number of passengers trips made using Japan Railways between two prefectures, is employed to capture a limiting effect of rail on demand for intercity coaches or to capture any intermodal competition. To capture the demand condition that is not captured by other basic explanatory variables such as the lodge variable, I include the TOP1 and TOP2 variables.[23] In line with Berry (1992), I use the distance between two prefectures composing a market as an explanatory variable. I expect that the variable affects both demand- and cost-side conditions in the market. Because some variables are recorded at the prefectural level, I convert them to market-level variables. Please see Table 2.3 for the detail. I provide summary statistics of variables at the prefectural-level in Table 2.4 and that at the market-level in Table 2.5. The entry data were collected as of 2018, while all other data were collected as of 2015.

[21]Specifically, passengers under 30 years old accounts for 22.2% of all intercity coach passengers. On the other hand, passengers under 30 years old accounts for 13.9% of all rail passengers on weekdays. In Japan, an Inter-Regional travel survey is conducted every 5 years. The survey asks passengers about their trip purpose and their demographic characteristics, and aggregated data are published by MLIT. The survey I refer to was conducted on a specific weekday and holiday in 2015. The aggregated data enable me to calculate age distribution in specific transport modes.

[22]Using the aggregated data for the inter-regional travel survey in 2015, I can calculate the distribution of trip purposes by intercity coaches. In the survey, the passengers choose their trip purpose from the options of private, pleasure-related (sightseeing), and business. The option of private includes homecoming. On a weekday, passengers whose travel purpose is a private account for 38.7% of all intercity coach passengers. Passengers whose travel purpose is business or sightseeing represent 31.2% or 30.1%, respectively. About the comparison with other transportation modes, the ratio of intercity coach passengers whose travel purpose is private is larger than that of other modes.

[23]The TOP1 and TOP2 variables capture the patterns of inter-prefectural transport in Japan, confirmed by Figure 2.2 when the other explanatory variables cannot fully capture the tendency.

Table 2.3: Descriptions of variables

variables	descriptions
population	Population size in a prefecture (in million persons).
income	Average income per year per capita in a prefecture (in million yen).
distance	Distance between the prefectural capitals of two prefectures (in 1000 km).
lodge	Total number of people lodging in accommodations in a prefecture traveling from any of the other prefectures per year (in million persons).
JR	Number of passenger trips between two prefectures composing a market by Japan Railway (in million passenger trips).
TOP1	Dummy variable which takes 1 if one of two prefectures composing a market has the largest population in its district. Japan consists of 9 districts: Hokkaido, Tohoku, Kanto, Hokuriku, Chubu, Kinki, Chugoku, Shikoku, and Kyushu. Each district consists of some prefectures.
TOP2	Dummy variable which takes 1 if both of two prefectures composing a market have the largest population in their district.
student	Ratio of high school and undergraduate students to the population in a prefecture (in %).
N	Number of operating firms in a market.
Q	Number of passenger trips between two prefectures composing a market by intercity coaches (in thousand passenger trips).
q	per firm per capita demand calculated by $q = Q/(N \times \text{population})$ (in thousand passenger trips).

Note: For the variables of population, income, lodge, and student, the values of these variables are at the prefectural level. To convert these variables into market-level variables, I take the mean of the values of two prefectures composing a market. For example, to construct the value of the population variable of the (Tokyo, Osaka) market, I take the mean of the values of the two prefectures: $\text{population}_{(\text{Tokyo,Osaka})} = \frac{1}{2} \times (\text{population}_{\text{Tokyo}} + \text{population}_{\text{Osaka}})$. However, about the variables of income and student, I use the weighted mean rather than the mean to construct the market-level variables. I use the value of the population of prefectures as the weight to calculate the weighted mean. I consturuct the market-level JR variable in the similar way of the variable Q.

Table 2.4: Descriptive statistics at prefectural-level

variables	unit	obs.	mean	s.d.	min	max	total
population	million persons	50	2.54	2.67	0.20	13.52	126.77
income	million yen	50	2.86	0.5	2.17	5.38	-
student	%	50	4.21	0.85	3.44	8.12	-
lodge	million persons	50	6.33	6.72	1.33	40.22	316.29
$JR_{A\to B}$	million passenger trips	1852	0.19	0.78	0	9.45	351.64
$Q_{A\to B}$	thousand passenger trips	1852	29.85	136.95	0	1866.9	55,272

Note: The variable of $Q_{A\to B}$ represents the number of passenger trips made from A prefecture to B prefecture by intercity coaches.

Table 2.5: Descriptive statistics at market-level

variables	unit	obs.	mean	s.d.	min	max
population	million persons	926	2.58	1.84	0.33	11.18
income	million yen	926	2.97	0.52	2.29	5.26
student	%	926	4.32	0.81	3.48	7.37
lodge	million persons	926	6.19	4.74	1.49	31.74
JR	million passenger trips	926	0.19	0.78	0.00	9.42
TOP1	integer	926	0.32	0.47	0	1
TOP2	integer	926	0.03	0.17	0	1
distance	1000km	926	0.47	0.29	0.03	1.37
N	integer	288	3.18	3.18	1	24
Q	thousand passenger trips	288	95.96	232.45	0.05	1824.9
q	thousand passenger trips	288	11.83	29.49	0.01	263.95

Note: Sample size are 926 except for N, Q, and q. I give the summary statistics of these variables calculated from the sample in which the markets with no operating firms are excluded. This is the reason why the sample size is 288 for N, Q, and q. The mean of the number of operating firms in a market calculated from the full sample is 0.99 and the corresponding standard deviation is 2.31.

Market definition and product differentiation

The definition of the market is related to the parameter α, which captures the degree of product differentiation. Because I define a market as a nondirectional pair of two prefectures, α is expected to capture two types of differences between firms in a market.

First, the parameter α captures pure product differentiation, which is created by marketing activities by firms. Some operating companies try to convince consumers that their services are different from those of other firms by, for example, providing Wi-Fi services or creating seats for women only. Also, some companies try to differentiate their services from those of others by emphasizing their operational safety.[24]

Second, the difference of route or timing among operating firms is also captured by α. Because I define a market as a nondirectional pair of two prefectures, some buses that travel along different routes and pass different bus stops are provided in the same market. This is not a product differentiation we want to capture. To make α capture only the first type of product differentiation, it might be possible to define the market as, for example, the city pair. However, if I define a market more narrowly, the strategic interactions that exist may be messed. Because the main research question of this study concerns evaluating the competitiveness of the industry, such strategic interactions should be taken into account. Consequently, I employ a nondirectional pair of two prefectures rather than a city pair as the market definition in this study.

2.4.2 Estimation results

Parameter estimates

OLS estimation of demand equation I first estimate equation (2.12) by OLS. I exclude markets for which there are no operating firms. Because there are many markets in which no firms provide services, the sample size for the OLS estimation is 288. The OLS estimation ignores the endogeneity of market structure, and therefore the possibility of estimation bias should be considered.[25] The estimation results are presented in Table 2.6.

[24] As already explained in Section 2.2, operational safety has become an important issue in Japan's intercity coach industry. Because accidents caused by express tour buses were widely covered by several mass media, consumers may prefer companies with good safety records.

[25] The direction of the estimation bias on α caused by OLS can be implied from the model: OLS overestimates α. The error terms in the model are ω in the entry equation (2.14) and ξ in the demand equation (2.12). The error term ω is the sum of ξ and error term $-\eta$ in the markup equation (2.11). To evaluate the sign of the bias, assume that η and ξ are statistically independent, which means that ω and ξ are negatively correlated: $\sigma_{\omega\xi} = E[\omega\xi] = -E[\xi^2] < 0$. Suppose ξ takes a large positive value. This means there is a positive shock to profit because ω and ξ are negatively correlated and $-\omega$ is in the profit function as in equation (2.8). The positive shock to profit encourages more entries. This is because ξ and $\log N$ are positively correlated and OLS overestimates α.

Table 2.6: OLS estimates of demand equation

	dependent variable
	$\log q$
income	-0.793^{***}
	(0.183)
student	0.383^{***}
	(0.099)
lodge	-0.064^{*}
	(0.035)
lodge × distance	0.203^{**}
	(0.083)
JR	0.170^{**}
	(0.079)
TOP1	1.017^{***}
	(0.168)
TOP2	0.097
	(0.297)
distance	-16.222^{***}
	(1.674)
distance^2	11.979^{***}
	(2.695)
$\log N$ $(= \alpha)$	-0.127
	(0.127)
Constant	4.341^{***}
	(0.561)
observations	288
R^2	0.522
adjusted R^2	0.505
residual std. error	1.227

Note: *p<0.1;**p<0.05;***p<0.01.

The values in the parentheses represent standard errors.

The coefficient of $\log N$ is the most interesting parameter because α represents the degree of product differentiation. The coefficient of $\log N$ is estimated to be $\hat{\alpha} = -0.127$. Because I do not control for the price, the estimates include the indirect effect of the market structure described in equation (2.17). Furthermore, α is overestimated by OLS because of endogeneity bias. If I ignore the above two concerns, the result that $\hat{\alpha}$ is close to zero suggests that the degree of product differentiation in the industry is significant. I subsequently quantify the effect of product differentiation on entry behaviors of firms using a counterfactual analysis because the qualitative interpretation of the estimated parameter is somewhat difficult.

I next consider the control variables in X. The average income negatively affects demand, and the ratio of students to the population positively affects demand. Both of these effects are statistically significant at the 1% level. The results indirectly[26] confirm that the intercity coach is used relatively often by low-income individuals in Japan. The effect of distance between two prefectures is negative and that of the quadratic term is positive, which indicates that the demand decreases up to 680 km and increases beyond that distance. Because the distances of two prefectures composing a market are shorter than 680 km in most markets having at least one firm, the result shows that the demand decreases with the distance in a market. To capture a probable heterogeneous effect of the lodge variable on demand, I include the interaction term between the lodge variable and distance variable and estimate that the coefficient of the interaction term is positive. The results indicate that the lodge variable positively affects demand on markets that have relatively long distances.[27] Even though I expect that the JR variable functions as a limiting factor of demand for intercity coaches and that the coefficient takes a negative value, it is estimated that the presence of JR has a positive effect on demand for intercity coaches. A plausible interpretation is that the JR variable captures potential demand for all modes of transport because it is expected that the potential demand for all modes of transport positively correlates with the JR variable.

Ordered probit model estimates Table 2.7 shows the estimation results of the ordered probit model. I assume that the variables included in X affect the logarithm of the ratio of variable profit to fixed cost as in equation (2.8). Even though the distance between two prefectures affects both variable profit and fixed cost, the other variables seem to affect

[26]We do not use direct data such as a passenger trip purpose survey in the estimation.

[27]In OLS estimation, the coefficient of the lodge variable is estimated to be negative with statistical significance. However, the effect is relatively small compared with the effect of the interaction term. Moreover, the negative effect of the lodge variable disappears in the estimate of simultaneous equation model.

only variable profit. Therefore, I assume that the variable whose estimated coefficient is positive is the profit-increasing factor except for the distance variable. Because variable profit is a product of demand and variable cost, whether these variables affect variable cost or demand is ambiguous and different among the variables.

The effect of income on variable profit is estimated to be negative. I have already confirmed that the effect of income on demand is negative from the OLS estimation. The estimation result of the ordered probit model is consistent with the demand equation estimates. In other words, income negatively affects demand, which in turn leads to a smaller variable profit and fewer entries of firms. The ratio of students has a positive effect on variable profit. The same logic in the interpretation of the coefficients on income is applicable; an increase in student ratio boosts demand, which increases variable profit and the entry of firms. The positive effects of the JR variable and the interaction term between the lodge variable and distance are also consistent with the result of the OLS estimation.

In contrast, although the TOP1 variable has a significant effect on demand, the estimates of the ordered probit model suggest that the TOP1 variable does not affect the profitability of intercity coach firms. I interpret why such a result is realized with simultaneous equation models.

Simultaneous equation model estimates Table 2.8 presents the estimation results of the simultaneous equation model. The estimation results of the demand equation are a little different from the result of the OLS estimation shown in Table 2.6.

The estimate of the coefficient of $\log N$ is $\hat{\alpha} = -0.394$. Comparing the result of Tables 2.6 and 2.8, we can confirm that OLS overestimates α. The estimate of the simultaneous equation model still suggests that the degree of product differentiation is significant in the industry. In addition, $1 + \alpha = 0.606$ indicates that a 1% increase in the number of firms existing in a market leads to a 0.606% increase in equilibrium demand, including the indirect effect of a decrease in price and the direct effect of an increase in product variety.

I next consider the control variables in X. In the same manner, as in the ordered probit model, I expect that the variables except for distance affect markup rather than fixed cost in considering the markup-fixed cost ratio equation described in equation (2.11) and on the left-hand side of Table 2.8.

The effect of income is negative in the demand equation and positive in the markup-fixed cost ratio equation. Although the markup of operating firms is positively affected by the average income of a market, the overwhelmingly negative effect on demand results in the negative effect on variable profit and entry. The student ratio of a market does not

Table 2.7: Ordered probit model estimates

	dependent variable
	log(variable profit/fixed cost)
income	−0.632***
	(0.112)
student	0.395***
	(0.057)
lodge	−0.012
	(0.021)
lodge × distance	0.228***
	(0.048)
JR	0.202***
	(0.064)
TOP1	0.088
	(0.086)
TOP2	0.026
	(0.177)
distance	−0.748
	(0.758)
distance^2	−5.937***
	(1.363)
θ_1	−0.309
	(0.322)
θ_2	−0.876***
	(0.327)
θ_3	−1.304***
	(0.337)
θ_4	−1.664***
	(0.352)
θ_5	−1.992***
	(0.370)
θ_6	−2.239***
	(0.386)
θ_7	−2.494***
	(0.405)
σ_ω	0.721
	(0.070)
observations	926
maxLL	−649.59

Note: *p<0.1;**p<0.05;***p<0.01. The values in the parentheses represent standard errors.

Table 2.8: Simultaneous equation model estimates

dependent variable					
log (markup/fixed cost)			log q		
income	0.378*	(0.200)	income	−0.996***	(0.196)
student	−0.088	(0.105)	student	0.478***	(0.104)
lodge	0.021	(0.038)	lodge	−0.033	(0.037)
lodge × distance	−0.009	(0.086)	lodge × distance	0.231***	(0.083)
JR	−0.017	(0.090)	JR	0.210**	(0.081)
TOP1	−1.080***	(0.174)	TOP1	1.163***	(0.173)
TOP2	−0.118	(0.300)	TOP2	0.131	(0.296)
distance	15.052***	(1.669)	distance	−15.826***	(1.654)
distance^2	−15.881***	(2.840)	distance^2	10.102***	(2.772)
δ_1	−4.517***	(0.568)	$\log N$ $(= \alpha)$	−0.394**	(0.186)
δ_2	−4.804***	(0.584)	Cosntant	4.192***	(0.559)
δ_3	−5.062***	(0.607)			
δ_4	−5.295***	(0.631)			
δ_5	−5.522***	(0.655)			
δ_6	−5.682***	(0.677)			
δ_7	−5.855***	(0.701)			
σ^2_ξ	1.506	(0.138)			
σ^2_ω	0.502	(0.095)			
$\sigma_{\xi\omega}$	−0.257	(0.097)			
observations	926				
maxLL	−1108.24				

Note: *p<0.1;**p<0.05;***p<0.01. The values in the parentheses represent standard errors.

affect markup. Therefore, the positive effect on variable profit is brought about only by the demand-side effect. The TOP1 variable has a positive effect on demand and hurts markup. The positive effect on demand is offset by the negative effect on markup, which induces the no-effect of the TOP1 variable on variable profit in the ordered probit model. I expect that the negative effect of the TOP1 variable on markup may capture a special characteristic of competition in such a market. In other words, competition in a market that connects two large cities is more intense. For example, competition in the (Tokyo, Osaka) market, which is actually classified as such a market, seems to be very intense even when I take into account that the market has many operating firms. I can confirm from the website from which I sourced the entry data, that the fare in the (Tokyo, Osaka) market is extremely low.[28]

ETR and markup ratio Table 2.9 shows the estimation results of ETR and markup ratio. Columns (1) and (2) are calculated using the estimates of the simultaneous equation model and equations (2.15) and (2.16), and column (3) is calculated using the estimates of the ordered probit model and equation (2.9). Note that the estimation results of the ETR in the ordered probit model are similar to that of the simultaneous equation model.

The values of ETR are not statistically larger than 1, even at the 10% level. As the intercity coach industry is highly differentiated, ETR tends to be under 1, even if the industry is actually competitive. Therefore, from these results, I do not conclude that the intercity coach industry is not in a competitive environment. Because market-level demand data are available, I can control for the market expansion effect from product differentiation to infer how markups change when one additional entry to the market occurs.

Controlling for product differentiation, different results regarding how competition intensifies can be seen. In column (1) in Table 2.9, the markup ratio always exceeds 1, which indicates that the entry of one additional firm always intensifies competition. Therefore, I conclude that the intercity coach industry is competitive and that the deregulations have competitive effects.

Specifically, column (1) in Table 2.9 also suggests that the markup gained by one firm under duopoly is estimated to be about three-quarters of that under monopoly. Moreover, the competitive effect of additional entry on markup is decreasing in N and the markup

[28]To interpret the negative effect of the TOP1 variable on markup, I give the example of the (Tokyo, Osaka) market and its low price, which seems to be caused by intense competition in the market. Note that I do not claim that a low price is caused only by intense competition. In intercity transport services, economies of scale are an important factor. As the positive effect of TOP1 variables on demand indicates, operating firms in a market whose TOP1 variable takes a value of 1 have large demand. Therefore, operating costs may be reduced, which induces low prices.

ratio tends to converge to 1 as the number of incumbents increases, which is consistent with the prediction from the usual competition model in industrial economic theory.

Table 2.9: ETR estimates

	(1)		(2)		(3)	
model	simultaneous				ordered probit	
	Markup_Ratio		ETR		ETR	
$N = 2$	1.332*	(1.850)	0.875**	(−2.128)	0.881**	(−1.972)
$N = 3$	1.293**	(2.569)	1.012	(0.204)	1.022	(0.365)
$N = 4$	1.263***	(2.745)	1.061	(0.966)	1.075	(1.123)
$N = 5$	1.254***	(2.726)	1.096	(1.355)	1.110	(1.467)
$N = 6$	1.173**	(2.132)	1.050	(0.790)	1.066	(0.960)
$N = 7$	1.189**	(2.131)	1.083	(1.122)	1.105	(1.290)

Note: I test the following.

$H_0 : \text{ETR}(N) = 1; H1 : \text{ETR}(N) \neq 1$ or

$H_0 : \text{Markup\_Ratio}(N) = 1; H1 : \text{Markup\_Ratio}(N) \neq 1$

The values in the parentheses represents t-statistics.

Counterfactual analysis

Product differentiation mitigates price competition and, hence, enables more firms to enter the market, as compared with a market without product differentiation. I quantify the effect of product differentiation on the possibility of entry by using counterfactual analysis. As I explained in Section 2.3.2, I measure the degree of product differentiation using the parameter α. When there is little or no room for product differentiation, α takes a value close to -1, and profitability in the market decreases as variety and demand for products decrease. I quantify the effects of product differentiation by comparing the average number of operating firms in a market the model predicts under the actual estimated parameters and counterfactual parameters.[29]

I discuss how to make predictions about the number of entering firms when product differentiation is prohibited or impossible using the simultaneous equation model. See equations (2.13) and (2.14), which represent the condition when just N firms enter the market whose demographics are X, the population is S, and the value of the error term is ω. Using this condition, if I set the parameter and the value of the error term, I can calculate the maximal number of firms that can profitably enter each market. I first set parameter values (c.i) $\alpha = -1$, (c.ii) $\alpha = -0.8$, or (a) $\alpha = -0.394$. In each case of (c.i), (c.ii), and

[29]Note that the estimated parameter $\hat{\alpha}$ captures the market expansion effect caused by the difference of route or timing in a market as I have explained in Section 2.4. This is why the counterfactual analysis overestimates the effect of product differentiation, which is caused by the marketing activities of operating firms.

(a), I set the other model parameters to the values estimated in the maximum likelihood estimation. Second, I set the value of the error term to 0. Third, I compute the maximal number of firms that can profitably enter each market under the alternative parameter values of (c.i), (c.ii), and (a), respectively. I then average these maximal numbers of firms over markets to obtain the expected number of entries over the industry. I compare the calculated expected number of entries over the industry under (c.i) or (c.ii) and that of (a) or the number observed in the data. I take such comparisons using the expected number of entries calculated using the full sample and the limited sample, in which the markets with no operating firms are excluded.

Table 2.10 presents the results. The first and second columns present the results using the full sample and the other columns present the results using the limited sample. The first and third columns show the difference in the number of entries between that predicted under the estimated parameter of (a) and that predicted under the counterfactual parameters of (c.i) or (c.ii). The second and fourth columns show the difference in the number of firms in the dataset and the predicted number of firms under the counterfactual parameter of (c.i) or (c.ii).

Table 2.10: Effects of product differentiation

	full Sample		limited sample	
	model prediction	actual	model prediction	actual
(c.i) $\alpha = -1$	0.28	0.64	0.89	2.16
(c.ii) $\alpha = -0.8$	0.24	0.60	0.76	2.03

Note: The values represent the difference between the expected number of entries under the counterfactual parameter and that under the estimated parameter in the first and third columns. In the second and fourth columns, the differences between the expected number of entries under the conunterfactual parameter and the actual number of firms in the dataare reported.

Because the sample includes many markets that are not sufficiently profitable for a potential entrant and hence having no operating firms, the results for the full sample and the limited sample are different. I focus on the results under the limited sample. The results show that if market participants are prohibited from differentiating their intercity coach services from each other ($\alpha = -1$), 0.89 firms have to exit on average because they generate no profit. Under weak prohibition of product differentiation ($\alpha = -0.8$), 0.76 firms have to exit the market on average. At the same time, this result means that 0.76 firms on average can enter a market by differentiating their products from each other.

2.5 Conclusion

In this study, I examined the economic effects of deregulation in the intercity coach industry in Japan. This industry has experienced two major deregulations. To evaluate the effects of these deregulations, I examined the intensity of competition in the industry. The absence of organized data for the industry motivated me to construct a newly constructed dataset. I constructed a unique dataset that captures the entry of bus operating companies, thereby addressing the question: have the deregulations intensified the competitiveness between operating firms?

The estimation results suggest that $ETR(N)$ does not exceed 1, even at the 10% significance level, which at first glance leads me to conclude that the Japanese intercity coach industry is not competitive. However, the conclusion from the estimates of $ETR(N)$ overlooks the market expansion effect through product differentiation. Controlling for product differentiation using a simultaneous equation model and market-level demand data enables me to estimate the effect of an additional entry on markup. The markup ratio always exceeds 1, which indicates that the entry of one additional firm always intensifies competition, and I conclude that the deregulations have competitive effects.

Specifically, the markup gained by one firm under duopoly is estimated to be approximately three-quarters of that under monopoly. Moreover, I showed that the effects of entry on markup decrease as the number of incumbents increases, which is consistent with the prediction from industrial economic theory. Note that this result is derived even though I do not assume a specific competition mode, such as Cournot or Bertrand competition. Furthermore, I quantified the effect of product differentiation on profitability. The counterfactual analysis reveals that 0.76 new firms can enter a market on average by differentiating their products from each other.

Although I revealed that the deregulations induced market participants to compete with each other, sufficient competition does not necessarily mean that social welfare is maximized. Mankiw and Whinston (1986) constructed a two-step entry game, which is similar to the theoretical setting in this study, and showed that social welfare is not maximized under Cournot competition even if free entry is allowed and the profit of each operating firm is zero. Berry and Waldfogel (1999) quantified the loss of social welfare caused by free entry into the radio industry. We generally have to assume a competition mode, such as Cournot competition, to estimate the loss of social welfare induced by free entry, as in Berry and Waldfogel (1999). The results for the estimates on markup ratio, which indicate that the effect of one additional entry decreases with the number of incumbents, will support the assumptions needed in future research or at least do not

contradict or reject the assumptions.

Finally, I point out the limitation of my modeling strategy and propose one prospective topic for future research. One limitation of this research is that the assumption of the independence of each market is restrictive. In both BR and SV models, potential entrants only consider whether they enter a specific market or not, and once they enter, they do not consider the economic conditions of the other markets. Since I adopt a nondirectional combination of two prefectures as a market definition, there is the possibility that two markets are adjacent to each other. In reality, operating firms in a market may consider entering the neighboring markets. When a firm enters a neighboring market, the entry conditions, such as fixed costs, are usually different between the firm and other potential entrants. This story is not consistent with the modeling assumption of independence among markets. In addition, the intensity of competition may be affected by the market structure of the neighboring markets. If many incumbents exist in the neighboring markets and the prices in the neighboring markets are low, the pressure of decreasing prices may exist.

Because considering mutual dependence among markets is difficult, Dürr and Hüschelrath (2018), who studied the entry behavior of two firms in the German interurban bus industry after the deregulation in 2013, also made a similar assumption. While Jia (2008) constructed a model that accommodates the dependence of markets, only two potential entrants exist in her model, which is not consistent with the empirical setting in this study. Constructing a more flexible model that allows multiple dependencies is an important topic that should be addressed in future research.

Chapter 3

Inference on noncooperative entry deterrence

3.1 Introduction

Strategic entry deterrence is one of the central research issues that continues to command attention in the field of industrial organization. It is essential to understand comprehensively the process by which firms deter entry and the consequences to devise an effective competition policy that aims to enhance market performance. Therefore, researchers in the industrial organization field have examined theoretically whether various firms' strategies are effective for entry deterrence (Tirole, 1988; Vives, 1999). Antitrust policymakers and researchers have been interested not only in how entry is deterred in theory but also in whether firms undertake entry-deterring strategies in the real world and how such behavior can be detected (Smiley, 1988; Lieberman, 1987). In this study, an empirical approach that detects strategic entry deterrence is proposed.

Compared with the significant advances in theoretical studies, there are relatively few empirical studies that provide evidence on strategic entry deterrence. One of the reasons why the number of empirical studies is small is that the existing studies largely focus on industries in which researchers can clearly identify the emergence of new entry threats; for example, patent expiration in the pharmaceutical industry (see Ellison and Ellison (2011)), entry plans in the casino industry (Cookson (2017)), and Southwest's endpoint operation in the airline industry (Sweeting et al. (2020)). Researchers provide empirical evidence after observing the change of incumbents' strategies around the emergence of such new entry threats. In general, however, it is difficult for researchers to identify new threats. Because the approach limits the potential for examining an industry in which

firms may have strategically undertaken entry deterrence and researchers cannot identify the emergence of entry threats that firms face, the number of empirical studies is small.[1]

Departing from the above approach, this study relies on conduct testing, which is used in the empirical industrial organization literature. Economists are interested in how firms compete in a specific industry and in determining which model of firm conduct is appropriate to describe the industry. In the conduct testing literature, to achieve this purpose, researchers construct and estimate various competing models of firm conduct, compare the models in a pair-wise manner, and determine which model has the best explanatory power.[2] More specifically, researchers identify the markup and marginal costs under the assumptions of competing models, estimate marginal cost functions, and statistically compare estimated cost functions using several criteria, including comparing the models' likelihoods using the Vuong-type model selection test (Vuong, 1989).

To apply the conduct testing approach in this study, I develop a structural econometric model of entry deterrence based on the industrial economic theory of Gilbert and Vives (1986). Furthermore, I show that incumbents' marginal costs are interval-identified under the assumption that incumbents deter entry in equilibrium. Specifically, the upper bounds of the interval-identified marginal costs correspond to the level of costs at which the incumbents are indifferent between deterring or allowing entry, whereas the lower bounds correspond to those identified under the assumption of Cournot competition. Using the upper bounds, I can test whether entry deterrence is more or less consistent with the data compared with other competing models of firm conduct. Because the upper bounds are used in the test, it is important to be aware that I will compare models in which the incumbents' conduct is most significantly influenced by entry threats with alternative models of firm conduct.

Given the purpose of this study described above, the Japanese aluminum smelting industry in the post-World War II period provides a good case study to examine empirically strategic entry deterrence. The history of the industry indicates that its incumbent firms were threatened by the entry of potential rival firms and that the incumbents were likely to undertake entry-deterring strategies. Furthermore, the simple characteristics of aluminum as a product prevents firms in the industry from using certain methods of entry deterrence, such as advertising or brand proliferation, which enables us to focus on the incumbents' commitment to production quantity as a candidate for an entry-deterrence strategy.

[1] Another reason why the body of empirical studies is relatively small is that "it is inherently difficult to distinguish strategic deterrence motives from other investment rationales" (Cookson, 2017).

[2] Although researchers previously used the conduct parameter method to understand the nature of competition in a market, e.g., Bresnahan (1982) and Porter (1983), the difficulties in estimating the conduct parameter are now recognized (Corts, 1999; Puller, 2009).

In this study, the structural model of entry deterrence is estimated with data relating to the Japanese aluminum smelting industry, and the model is statistically compared with other models of firm conduct by adopting a model selection test developed by Rivers and Vuong (2002). Recent studies, Backus et al. (2021) and Duarte et al. (2020), propose using generalized method of moments (GMM) objective functions based on excluded instruments for marginal cost as a criterion in the framework of Rivers and Vuong (2002). Certain instruments that are appropriate in a differentiated product industry, such as the product characteristics of other firms, are difficult to obtain in a homogeneous product setting. The data on the industry include (other) firms' cost efficiency measures, which is an appropriate instrument. Therefore, it is performed that not only the test that does not rely on any instruments and several previous studies adopt but also the test employing the instrument.

The result of these tests suggests that the entry-deterrence model is more consistent with the data than the Cournot competition model. However, the perfect competition model is almost as consistent with the data as the entry-deterrence model. Furthermore, because the data include a sample of firms for which the threat of entry has disappeared, I compare firm conduct with and without entry threats. The result shows that after the threat of entry disappeared, the Cournot competition and perfect competition models are both consistent with the data, with the former being slightly more consistent.

3.1.1 Related literature

This study is related to two strands of literature in the field of industrial organization. The first strand comprises studies that aim to provide empirical evidence of strategic entry deterrence. A common approach adopted by the existing studies is examining different investment strategies between firms in situations with and without entry threats. The seminal work by Lieberman (1987) investigates whether incumbent firms strategically maintain excess capacity in a chemical industry that is rapidly growing. If an incumbent has an incentive to deter entry by potential rivals in a growing industry, the growth rate and the capacity utilization rate sufficient to elicit new capacity installation is lower for incumbents than for entrants. However, Lieberman (1987) shows that entrants and incumbents exhibit similar investment strategies. Cookson (2017) examines whether capacity expansion strategies vary between incumbents facing entry threats and those without entry threats. The casino entry plan data on which Cookson (2017) focuses enables him to identify clearly whether an incumbent is threatened by entry plans because the data include information on the planned site of a proposed entrant. By employing a

difference-in-difference method, Cookson shows that incumbents expand their capacity with a motive to deter entry. Ellison and Ellison (2011) introduce a novel approach for empirically examining entry deterrence. They prove that there is nonmonotonicity between market size (or attractiveness for entry) and strategic investment under entry-deterrence motives that does not exist if firms do not invest for the purpose of entry deterrence. Therefore, they propose testing the monotonicity between market size and incumbents' investment to examine strategic entry-deterrence behavior. Sweeting et al. (2020) adopt Ellison and Ellison (2011)'s approach to examine limit pricing. The present study contributes to this literature by presenting new empirical evidence in environments where the methods described in the existing literature are not applicable.

Several studies in this strand of literature rely on a structural econometric approach. To investigate the entry-deterrence impact of code-sharing, which is a form of strategic alliance in airline industries, Gayle and Xie (2018) estimate a dynamic structural model of entry and exit in the tradition of Ericson and Pakes (1995). They show that code-sharing influences potential entrants' market entry costs and thereby effectively functions as a means of entry deterrence. In addition, they demonstrate that entry costs vary according to the form of code-sharing and the identity of entrants. From the viewpoint of predation differing from entry deterrence, Snider (2009) and Williams (2012) show that incumbent firms in the US domestic airline industry had predatory incentives when they invested in capacity building and thereby induced entrants to exit.

The second strand of literature to which this study contributes is concerned with the issue of conduct testing and identifying markup and marginal cost based on model assumptions. Understanding firm conduct is not only of general interest for researchers but also a fundamental component of structural models used for policy evaluation. Therefore, researchers in the industrial organization field have developed and empirically tested various structural models describing firm conduct. Several studies use pair-wise model selection tests for nonnested models originally developed by Vuong (1989) and then extended by Rivers and Vuong (2002). The tests have been applied to various economic issues, including collusion (Gasmi et al., 1992; Doi and Ohashi, 2019), vertical relationships (Sudhir, 2001; Bonnet and Dubois, 2010), and common ownership (Backus et al., 2021). Berry and Haile (2014) generalize Bresnahan (1982)'s idea of "demand rotation" to identify the degree of competition and derive testable restrictions to distinguish empirically between alternative models of oligopoly competition. Based on Berry and Haile (2014)'s arguments, Backus et al. (2021) and Duarte et al. (2020) propose a test using a GMM objective function based on excluded instruments from a marginal cost function as a criterion in Rivers and Vuong (2002)'s test framework. Furthermore, Backus et al.

(2021) propose an optimal instrument for testing when many instruments are available. This study contributes to this literature by providing identification results for marginal cost using an entry-deterrence model based on Gilbert and Vives (1986), and by testing the model using data on the Japanese aluminum smelting industry.

The remainder of this chapter is organized as follows. Section 3.2 introduces the model describing the entry-deterrence behavior of incumbent firms and presents the identification method for the incumbents' marginal cost. Section 3.3 provides an overview of the development of the Japanese aluminum smelting industry. Section 3.4 presents the specification employed for empirical analysis, elaborates on the data set used, and provides estimation and testing results. Section 3.5 concludes by summarizing the main results and identifying topics for future research.

3.2 Model and identification of marginal costs

In this section, a theoretical model of strategic entry deterrence based on Gilbert and Vives (1986) is developed, and then I show that the marginal costs of incumbents are interval-identified.

3.2.1 Settings

A two-stage game with complete information is considered. There are M incumbent firms and a potential entrant. Both the incumbents and the entrant produce a homogeneous product. Let i represent a generic incumbent and e represent the entrant. At the first stage of the game, the incumbent firms independently make their respective production decisions. In the second stage, the potential entrant decides whether to enter and its level of production, if it does enter, given the incumbents' first-stage output. The entrant incurs a sunk entry cost if it enters. Given the total output, the market-clearing price is realized.

Incumbent firm i's cost function is assumed to be $C_i(x) = c_i x$, where $c_i \geq 0$ is a positive constant that differs between incumbents, and x represents a level of production. Meanwhile, the entrant has a cost function of $C_e(x) = c_e x + F$ if $x > 0$, and zero otherwise, where $F \geq 0$ is a sunk entry cost and $c_e \geq 0$ is a constant marginal cost for the entrant.

Let $P(X)$ denote the inverse demand function, where X represents the industry total output. I assume that $P(X)$ is twice continuously differentiable, downward sloping, $P' < 0$, and concave, $P'' < 0$, whenever $P(X)$ is positive. In addition, I assume that there exists a value of $\xi > 0$ such that $X \geq \xi \Rightarrow P(X) = 0$.

As a further assumption, ignoring entry for a moment, let $r(Z, c)$ be the optimal level

of output for an incumbent firm with marginal cost c when the other firms produce a total output of Z. In other words,[3]

$$r(Z, c) = \underset{x}{\operatorname{argmax}}\, P(x + Z)x - cx. \tag{3.1}$$

The convexity of the response function $r(Z, c)$ in Z is assumed.[4]

The potential entrant actually enters the market if the profit it earns as a Stackelberg follower exceeds the sunk entry cost; otherwise, it does not enter. Because the profit that the entrant earns as a Stackelberg follower is decreasing in the first-stage total output, there exists a minimum level of first-stage total output that induces the entrant to give up entering the market. It is called the critical limit output, Y, for the oligopoly and satisfies the following equation:

$$\pi_e\left(r\left(Y, c_e\right), Y\right) = F,$$

where $\pi_e(r(Y, c_e), Y) = (P(r(Y, c_e) + Y) - c_e)r(Y, c_e)$ is the maximum profit that the entrant can earn as a Stackelberg follower.

3.2.2 Best response function and entry-deterring equilibrium

Gilbert and Vives (1986) analyze the model described above with cost homogeneity between the incumbents and an entrant, derive the best response function for incumbents, and characterize the equilibria of the game according to the level of critical limit output Y. Let $\phi_i(Z)$ denote the best response of firm i when the other incumbents produce a total output of Z. Depending on the level of Z, firm i may or may not have an incentive to deter entry.

On the one hand, when Z is sufficiently large to satisfy $r(Z, c_i) + Z \geq Y$, incumbent i produces $r(Z, c_i)$ and then entry is blocked because the first-stage total output, $r(Z, c_i) + Z$, exceeds Y. On the other hand, entry cannot be blocked if Z is not sufficiently large to satisfy $r(Z, c_i) + Z \geq Y$. In this case, firm i may either allow entry or prevent it. Firm i can prevent entry by producing $Y - Z$ and making up the difference between Y and Z.[5] However, the smaller Z becomes, the more firm i needs to produce to make up the difference and the lower is its incentive to prevent entry. Therefore, when Z is sufficiently

[3]Thus, $r(Z, c)$ is the Cournot best response.

[4]The convexity is also assumed in Gilbert and Vives (1986). This assumption simplifies the analysis of the incumbents' optimal production decision as a Stackelberg leader.

[5]Incumbent i has no incentive to produce an amount larger than $Y - Z$ because $Y - Z > r(Z)$ when $r(Z) + Z < Y$.

small, firm i gives up deterring entry and allows entry. When firm i chooses to allow entry, it behaves as if it were a Stackelberg leader. Therefore, the best response of firm i is summarized in the following equation (3.2), with the derivation provided in Appendix A.1:

$$\phi_i(Z) = \begin{cases} r(Z, c_i) & \text{if } Z \geq \overline{Z}(Y, c_i), \\ Y - Z & \text{if } \underline{Z}(Y, c_i, c_e) \leq Z < \overline{Z}(Y, c_i), \\ s(Z, c_i, c_e) & \text{if } 0 \leq Z < \underline{Z}(Y, c_i, c_e). \end{cases} \tag{3.2}$$

Here, $\overline{Z}(Y, c_i)$ and $\underline{Z}(Y, c_i, c_e)$ represent the threshold production levels of the other incumbents at which firm i can block or prevent the potential entrant from entering. More specifically, $\overline{Z}(Y, c_i)$ is the minimum output level produced by the other incumbents at which incumbent i can block entry, and it is the solution of equation $r(Z, c_i) + Z = Y$ for Z. $\underline{Z}(Y, c_i, c_e)$ is the minimum output level at which incumbent i has an incentive to deter entry. When $Z = \underline{Z}(Y, c_i, c_e)$, the profit when firm i prevents entry is equal to the profit when it produces $s(Z, c_i, c_e)$ and allows entry. The optimal production level when entry is allowed and firm i plays the role of a Stackelberg leader is represented by $s(Z, c_i, c_e)$. The following result, which proves the existence of entry-deterring equilibria, presented by Gilbert and Vives (1986), is important for the identification of marginal costs.

Proposition 1 (Gilbert and Vives 1986)
Assume that $c_i = c_e = 0$. Let X^C be the total output in the Cournot equilibrium between incumbents, let $\overline{Y}$ be the largest Y such that the ϕ's intersect on the hyperplane $\sum_{i=1}^{M} x_i = Y$, and let X_{-i} be $\sum_{j \neq i} x_j$. If $X^C \leq Y \leq \overline{Y}$, then any $x = (x_i)_{i=1}^{M}$ in the set $\mathcal{E} = \{x \in \mathbb{R}_+^M \mid \sum_{i=1}^{M} x_i = Y, r(X_{-i}, c_i) \leq x_i \leq Y - \underline{Z}(Y, c_i, c_e)\}$ and the potential entrant remaining out of the market is a subgame perfect equilibrium. Incumbents prevent entry by producing a total output of Y.

Proof. See Gilbert and Vives (1986). ■

Even in the presence of cost heterogeneity, it can be shown that any incumbent i has no incentive to deviate from its equilibrium strategy if $x = (x_i)_{i=1}^{M}$ is in the set $\mathcal{E}$ because the incumbent's best response function remains unchanged even if cost heterogeneity is introduced.[6] In other words, entry-deterring equilibria exist even when cost heterogeneity

[6]Take the incumbent's strategy $(x_i)_{i=1}^{M}$ in an equilibrium. Consider whether incumbent i has an incentive to deviate from x_i. Because $r(X_{-i}, c_i) < x_i$ is satisfied, firm i has no incentive to increase its production level. Furthermore, $x_i \leq Y - \underline{Z}(Y, c_i, c_e)$ and $\sum_{i=1}^{M} = Y$ means that $X_{-i} \geq \underline{Z}(Y, c_i, c_e)$. Therefore, firm i has an incentive to deter rather than allow entry given X_{-i}. Moreover, the entrant has no incentive to enter the market because the limit output Y is produced in the first stage.

is introduced. For the marginal cost identification analysis, the equilibria represented by the set $\mathcal{E}$ are focused.

3.2.3 Identification of marginal cost

To consider the identification problem concerning the incumbents' marginal cost $(c_i)_{i=1}^M$, it is necessary first to define the observables for a researcher. A researcher can observe the market price P and the firm-level output $(x_i)_{i=1}^M$. The researcher need not observe entry cost F, but it is assumed that the marginal cost of a potential entrant c_e is observable. Although the assumption that c_e is known is strong, it is realistic that a researcher has prior knowledge of the range of possible values for a parameter. That is, a researcher knows that c_e falls into a known interval of $[\underline{c}_e, \overline{c}_e]$. In this case, conservatively to construct an identification region for the incumbents' marginal cost, let c_e be $\underline{c}_e$.[7]

To identify the incumbents' marginal cost, the following proposition is beneficial. The proposition shows that firms with higher marginal costs are less willing to deter entry if other firms do not produce a sufficient amount.

Proposition 2 *When $\underline{Z}(Y, c_i, c_e) > 0$, $\underline{Z}(Y, c_i, c_e)$ is strictly increasing in c_i.*

Proof. See Appendix A.2. ■

Assume that an entry-deterring equilibrium is realized in the data, that is, $(x_i)_{i=1}^M \in \mathcal{E}$. Therefore, the quantity that a researcher observes satisfies:

$$r(X_{-i}, c_i) \leq x_i \leq Y - \underline{Z}(Y, c_i, c_e). \tag{3.3}$$

Because $\underline{Z}(Y, c_i, c_e)$ is strictly increasing in c_i and $r(X_{-i}, c_i)$ is strictly decreasing in c_i, given the other arguments, both functions have their inverse functions, denoted by $\underline{Z}^{-1}(Y, ., c_e)$ and $r^{-1}(X_{-i}, .)$, respectively. Therefore, equation (3.3) can be rearranged as:

$$r^{-1}(X_{-i}, x_i) \leq c_i \leq \underline{Z}^{-1}(Y, Y - x_i, c_e). \tag{3.4}$$

Note that the limit output Y is observable because it corresponds to incumbents' total output $X = \sum_i x_i$ in any entry-deterring equilibrium. Therefore, both side of equation (3.4) are identified from the data.

To apply the data to equation (3.4), it is necessary to be able to compute the function on both sides. Because the function on the left-hand side is the inverse of the Cournot best

[7] I clarify why this is sufficient to conservatively construct the identification region for marginal costs in Appendix A.3.

response, it can be calculated from the first-order condition of the optimization problem (3.1), as in previous studies. Conversely, the function $\underline{Z}^{-1}(Y, Y - x_i, c_e)$ may not be solved analytically, depending on the shape of the demand function. Appendix A.3 provides a method to calculate the value of the right-hand side of equation (3.4) numerically.

3.3 The Japanese aluminum smelting industry post-WWII

In this section, I describe the post-World War II development of the Japanese aluminum smelting industry. There are several reasons why the postwar industry data are appropriate for empirical research on entry deterrence. First, incumbent firms operating in the industry evidently faced the threat of entry and hence were likely to undertake entry-deterring strategies. Second, because the properties of aluminum are simple and hence it is difficult to produce differentiated products, firms operating in the industry could not use various methods of entry deterrence, such as brand proliferation or advertisements. Furthermore, during the sample period on which I focus, it is unlikely that overcapacity was employed as an entry barrier. Over the sample period, the industry operating ratio, which is defined as the ratio of annual production over annual capacity, was 0.89 on average. Third, because the 1973 oil crisis changed the market environment and profitability of the business, it is possible to compare firm conduct with and without entry threats by dividing the whole sample into two subsamples, before and after 1973. This section describes the development of the industry and describes aluminum production to guide the empirical specification in Section 3.4.[8]

The Japanese aluminum smelting industry experienced a remarkable rise and decline during the period of analysis. Postwar aluminum smelting in Japan began with three incumbent firms, Nippon Light Metal, Sumitomo Chemical, and Showa Denko. With the rapid growth in demand, these incumbent firms expanded their smelting facilities, and new companies, Mitsubishi Chemical, Mitsui Aluminum, and Sumikei Aluminum, entered the industry. As a result, the total annual capacity grew from about 65,000 tons in 1955 to 1,640,000 tons in 1978. However, the two oil crises of 1973 and 1979 sharply increased the cost of aluminum smelting and deprived the industry of its global competitiveness and prosperity. As a result, by 1987, all except one plant had closed, and almost all domestic aluminum demand has been satisfied by imports since then. The focus of our study is on this period of dramatic change.

The postwar Japanese aluminum industry is characterized by a three-level vertical

[8]Goto (1988) provides a good overview of the development of the industry and a description of public policy concerning the industry after the oil crisis.

supply chain consisting of (i) aluminum smelting, (ii) processing, including rolling, extrusion, and die casting, and (iii) production of final consumer products. At the first level in the supply chain, firms produce aluminum ingots from raw materials, such as imported bauxite. At the second level, aluminum undergoes processing, for example, rolling and heat treatment to harden it. After processing, aluminum has the properties required to make a final product at the third level of the supply chain. Each level of the supply chain comprises vertically separated companies. The focus of this study is the first level of the supply chain.

There are two types of aluminum used in the second and third levels of the supply chain: primary aluminum, which is made from bauxite, and secondary aluminum, which is made from aluminum products that have been discarded as waste. Primary and secondary aluminum differ in their levels of purity and uses. Our focus is on primary aluminum, which has purity levels of 99.0%–99.9%.[9]

Although aluminum is used in a variety of applications, an increase in demand from the construction and transportation sector supported the rapid growth. Table 3.1 shows the volume of product shipments in the second level of the supply chain classified by shipping destinations. The table shows that shipments to the transportation and construction sectors increased significantly in the 1960s and 1970s. The increase in shipments to the construction sector is particularly noteworthy, rising from 3% of total shipments in the 1950s to 33% in the 1970s. This was a result of the rapid increase in popularity and spread of aluminum window sashes during the same period. In contrast, shipments to the construction sector in the 1980s did not grow as much as previously. Figure 3.1 shows the volume of demand for aluminum and a measure of construction activity, which is the total floor area of the buildings on which construction had commenced. Demand is represented by the sum of domestic production and imports of primary aluminum. The figure also suggests that demand from the construction sector was the main driver of growth in the industry.

The demand for aluminum in postwar Japan continued to increase during the 1970s, but the domestic suppliers began to be replaced by overseas producers (imports). The oil crisis took a heavy toll on the Japanese aluminum smelters. Figure 3.1 shows that after the 1973 oil shock, domestic production fell and imports rose. Although imports continued to rise after 1973, domestic production did not increase in the 1970s, and when the second oil shock occurred in 1979, domestic production fell sharply. The reason why the oil crisis hit the domestic smelters so hard relates to the main raw material for aluminum and how

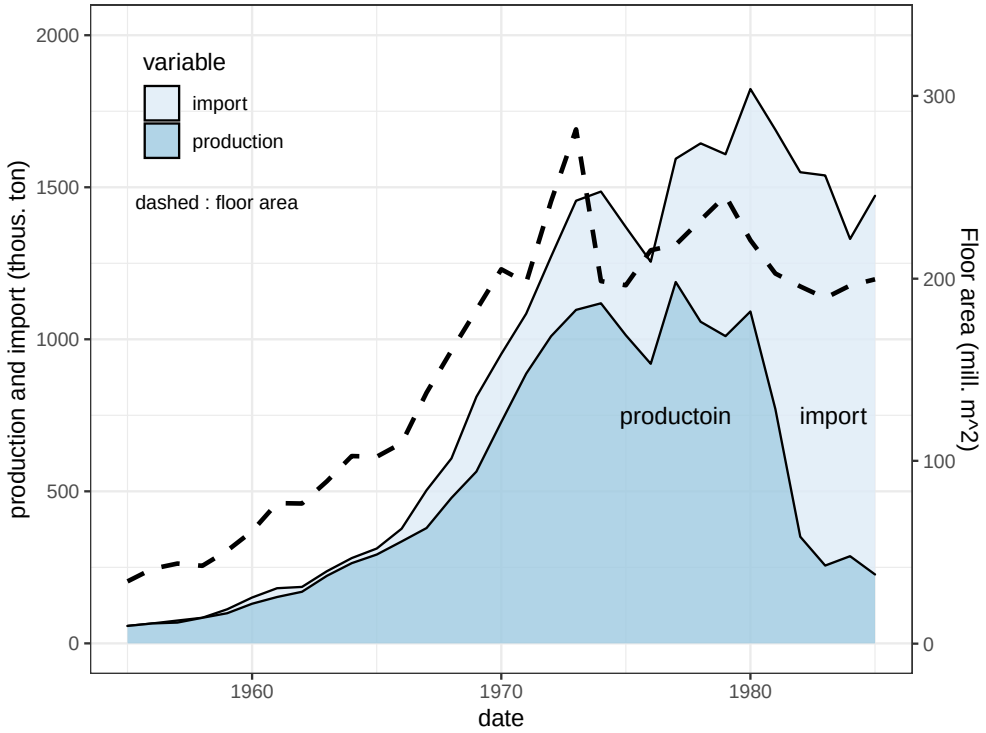
[9]Suslow (1986)'s empirical analysis shows that the price of secondary aluminum does not influence the demand for primary aluminum.

Table 3.1: Shipments by destinations

Year	Total Shipment	Transport	Construction	Metal Product	Packaging	Others
1950–1959	81 (100%)	10 (13%)	2 (3%)	16 (20%)	1 (3%)	51(63%)
1960–1969	497 (100%)	106 (21%)	78 (16%)	83 (17%)	6 (1%)	225 (45%)
1970–1979	1729 (100%)	366 (21%)	571 (33%)	240 (14%)	67(4%)	485 (28%)
1980–1989	2625 (100%)	761 (29%)	747 (28%)	376 (14%)	173 (7%)	568(22%)

Note: Secondary stage annual shipments by shipping destinations in thousand tons. Averaged over 10 years are listed. The values in the parenthesis are the ratio of shipment to the destination over the total shipment. Since the raw materials used in the second stage include not only primary aluminum but also secondary aluminum, the total shipment in the table is larger than the value of primary aluminum demand in Figure 3.1.

Figure 3.1: Demand and construction activity



it was sourced by domestic smelters.

Although the main raw material for aluminum is bauxite, the production of aluminum is highly electricity-intensive. Aluminum is produced by electrolyzing the intermediate product alumina (or aluminum oxide), employing the Hall–Héroult process, after the alumina is extracted from bauxite by the Bayer process. The electrolyzing process requires a large amount of electricity. Specifically, approximately 15,000 kWh of electricity is consumed in the Hall–Héroult process to produce a unit ton of aluminum[10] and the electricity costs accounted for about 25% of total costs even before the oil crisis (Miwa, 2016).

In addition, Japanese smelters relied mainly on oil-fired thermal power generation to meet their electric power needs, whereas overseas smelters could use low-cost electricity generated by hydropower (Peck, 1988). Therefore, the oil crisis increased the electricity costs of aluminum smelting for Japanese firms in particular. Figure 3.2 shows crude oil, imported bauxite, and aluminum prices. The 1973 oil shock raised the price of oil threefold and the 1979 shock further increased it to more than seven times the level before the oil crisis. These increased oil prices led to the decline in the share of domestic firms' production seen in Figure 3.1.

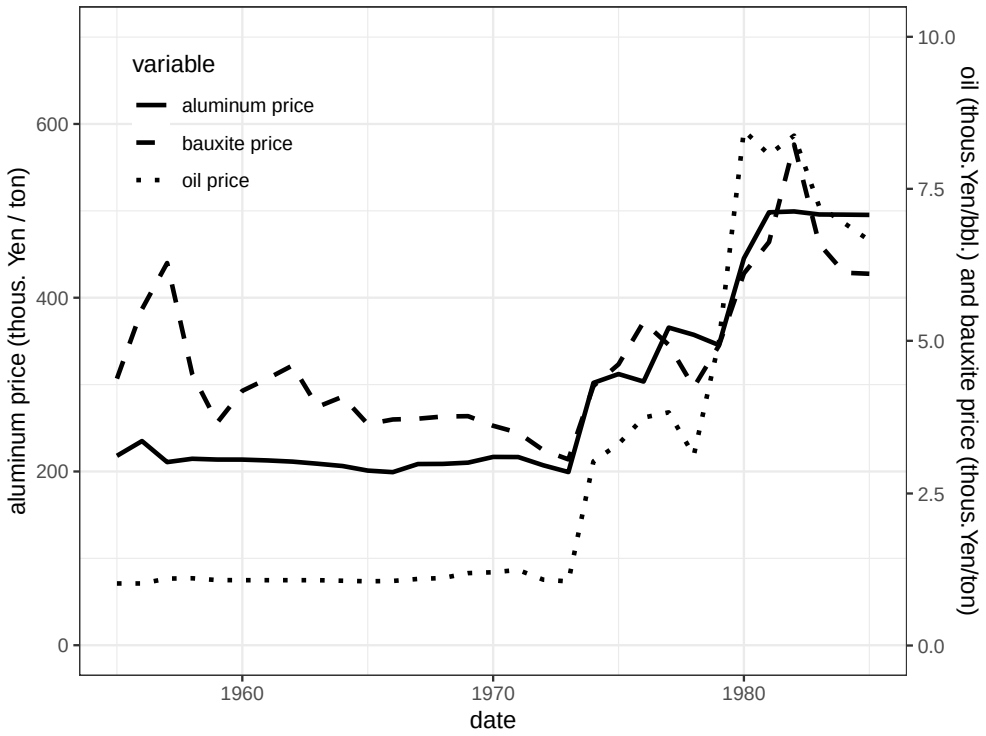
The presence and disappearance of entry threats Before the oil crisis, the aluminum industry had substantial profits, making it attractive to potential new entrants. In October 1960, the first entry plan since the end of the war was reported in a newspaper. Nisso Steel, an open hearth furnace steel manufacturer and a group company of Yahata Steel Corporation, an integrated steel manufacturer, planned to commercialize aluminum smelting. Yahata Steel, which had shown interest in aluminum production before the report, took a leading role in the commercialization of aluminum and expanded and revised Nisso's plan to include aluminum processing as well as smelting. There was fierce opposition to Yahata's plan to enter the aluminum smelting and processing industry from the three existing companies.

In response to this opposition, the Ministry of International Trade and Industry (MITI) postponed approval of the entry. Ultimately, entry into the smelting sector was abandoned, and a new company, Sky Aluminum, which engaged only in the processing business, was established and began operating in 1967.

The threat of entry remained for the three existing firms even after Nisso (and Yahata) withdrew their plans to enter the smelting industry. Mitsubishi Chemical announced its

[10]Because of successive innovations in the smelting process, the electricity intensity declined in the sample period.

Figure 3.2: Aluminum, oil, and bauxite prices



intention to enter the industry in December 1960, about the same time as Nisso's entry plan announcement, and Mitsui Aluminum was established as an aluminum smelting business as a joint venture of the Mitsui group companies in January 1968. As in the case of Nisso, the incumbent companies opposed the entry plans of Mitsubishi Chemical[11]. In this case, despite their opposition, the entry did occur. Mitsubishi commenced operations in May 1963 at Naoetsu city in Nigata prefecture and Mitsui Aluminum began to operate in January 1971 at Miike in Fukuoka prefecture.

The 1973 oil crisis significantly altered the aluminum smelting industry in Japan, which relied on oil-fired thermal power generation to produce aluminum. After the oil shock, smelting was no longer a lucrative industry. Indeed, two companies (Kobe Steel and Furukawa Aluminum) had planned to enter the industry before the oil shock, but both abandoned these plans immediately after the oil shock. Thus, after the oil shock, the industry was no longer subject to entry threats.

Based on the above overview of the industry, I model its structure, including demand

[11]The existing companies were not as strongly opposed to the entry of Mitsubishi Chemical as they were to the entry of Nisso (Yahata) and Mitsui. This may be because Mitsubishi had stated that it would only supply aluminum ingots to Mitsubishi group companies and that any excess production would be exported (Neo, 2003). Moreover, the three incumbents may have been tolerant of Mitsubishi Chemical as a means of deterring more powerful rivals (Ashiya, 2000).

and costs, select the variables used in the analysis, and split the whole sample into the two subsamples, before and after the 1973 oil shock. Finally, it is noteworthy that several industrial policies were implemented by the MITI after the oil shocks, particularly in the late 1970s and early 1980s, that are not explicitly modeled in the empirical analysis. The objective of the industrial policies was not to aid and sustain the industry[12], but to promote the reduction of excess capacity, which had been brought about by the increased electricity costs. Specifically, from 1978, existing companies could receive an annual sum equivalent to approximately 6% (annual interest rate) of the book value of their "frozen" capacity[13]. Because the industrial policies would have affected the dynamic incentives of firms in relation to their capacity choices, but would not have influenced static competition, I exclude analysis of the policies from the scope of this study.

3.4 Empirical analysis

By comparing alternative economic models that describe the competition in the Japanese aluminum industry, it is possible to test whether the incumbent firms attempted to deter entry by committing to excessive production output. The three models of competition tested are the: (i) Cournot, (ii) entry-deterrence, and (iii) perfect competition models. Because marginal costs are interval-identified under the assumptions of the entry-deterrence model, I use the upper bounds on marginal costs for the entry-deterrence model.

Employing the upper bounds has the following two implications[14]. First, employing the upper bounds assumes a specific equilibrium arises in the data. Although there are multiple equilibria in which entry is deterred, firms taking an entry-deterring strategy produce more than they would produce if no entry threat existed. Because the total output in a Cournot equilibrium is decreasing in firms' marginal costs, the difference between the counterfactual Cournot total output of incumbents with marginal costs equal to the upper bounds and the observed limit output becomes as large as possible. In other words, employing the upper bounds means that the equilibrium arises where the firms' output is maximally affected and increased in response to the threat of entry.

Second, the test using specific values of partially identified parameters, like this study, may give implications for the result of a formal test where two partially identified models

[12]The existing businesses requested that the government offer exceptionally low electricity rates as an industrial policy, but their request went unheeded.

[13]Smelting equipment that became technically unusable after a certain period was referred to as "frozen."

[14]It is common to employ a specific value for partially identified parameters in the industrial organization literature to enable the analysis to proceed. For example, Wollmann (2018) uses the midpoints of bounds on partially identified parameters for sunk costs to perform a counterfactual analysis.

are compared, when the formal test is infeasible. Shi (2015) develops a Vuong-type model selection test where two moment inequality models are compared.[15] The moment inequality conditions give a set of distributions that are consistent with those conditions. Then, the test developed by Shi (2015) selects between two moment inequality models, by choosing the one model that includes a distribution closer to the true distribution. In other words, the test is structured to compare the best distributions of each of the two models. Given the test structure, when the specific values of partially identified parameters are used and favored over the point-identified model, this may mean that the partially identified model will be favored in a formal model selection test developed for partially identified models. However, this is intuition and not a mathematical result. The test structure of Shi (2015) is not appropriate for this study because the determination of firm conduct should be based on a criterion formed from excluded instruments (Berry and Haile, 2014), whereas the test developed by Shi (2015) prohibits this treatment.[16]

3.4.1 Demand and cost specification and testing method for firm conduct

Demand function To test firm conduct, it is necessary to estimate a demand function. A log-linear demand function for aluminum demand is specified as follows:

$$\log Q_t = \alpha_0 + \alpha_1 \log P_t + \alpha_2 \log X_t + \epsilon_t^D, \tag{3.5}$$

where Q_t is the sum of domestic production and imports, P_t is the aluminum ingot price, X_t denotes demand shifters, and ϵ_t^D represents an unobserved demand shock. The shifter X_t includes the total floor areas of buildings on which construction had commenced in a period, a linear time trend, and month fixed effects.

Because there appear to be delays in the effect of the total floor area on aluminum demand, as seen in Figure 3.1, the 12-month moving averages are used in the demand analysis. The parameters of the demand function are estimated by two-stage least squares (2SLS) using the imported bauxite price, the oil price, and the average electricity intensity as instrumental variables for the aluminum price P_t. The electricity intensity, which is often used as a measure of inefficiency in the industry, can be calculated as the ratio of the consumption of electricity to production output.[17] Because the unobserved demand shock

[15] Moment inequality models include moment equality models. In addition to Shi (2015), Hsu and Shi (2017) develops a Vuong-type model selection test for conditional moment inequality models.

[16] To my knowledge, a formal model selection test that enables the treatment has not been developed.

[17] Although the electricity intensity is calculated using production quantities, which are endogenous, it

ϵ_t^D may involve serial correlation, the standard errors of estimates are adjusted following Newey and West (1987).[18]

Cost function To proceed with the test, the cost function for a firm engaging in aluminum smelting needs to be estimated. A linear marginal cost function for aluminum smelting is specified as:

$$MC_{jt} = \beta_0 W_t + \beta_1 W_{jt} + \gamma_j + \epsilon_{jt}, \tag{3.6}$$

where MC_{jt} is the constant marginal cost for firm j at time t, W_t and W_{jt} are exogenous cost shifters, γ_j is a firm fixed effect, and ϵ_{jt} is an unobserved cost shock. The cost shifter W_t, which is common between firms, includes the bauxite price, a time trend, and month fixed effects, whereas the shifter W_{jt}, which varies between firms, includes the product of the crude oil price and firm-level electricity intensity (rather than just electricity intensity), $W_{jt} = \text{oil price}_t \times \text{electricity intensity}_{jt}$.

In the cost analysis, I use the 12-month moving average for the oil price. This is because not all smelters had their own thermal power generation equipment. In other words, several firms met their power needs by buying electricity. Because the price set by electricity companies does not immediately reflect the rise in oil prices, I assume oil prices have a delayed effect on firms' marginal costs.[19] I expect the firm fixed effects in the cost function (3.6) capture the differences among how firms sourced their power needs.

Given that the demand function has already been estimated, it is possible to identify marginal costs under different assumptions for competition. If the Cournot model is assumed to describe the competition in the industry, marginal costs can be identified using the first-order condition and estimated as follows:

$$\widehat{MC}_{jt}^{C} = P_t(1 + \frac{q_{jt}}{Q_t}\frac{1}{\hat{\alpha}_1}). \tag{3.7}$$

where q_{jt} is each firm's production quantity and $\hat{\alpha}_1$ is the estimated price elasticity of demand. If the entry-deterrence model is assumed to represent industry competition, the

is not an endogenous variable because the value does not depend on the utilization rate and only reflects a technological aspect.

[18]Boyd et al. (1995) assume that the unobserved demand shock follows an AR(1) process in the case of US primary aluminum demand.

[19]Due to the same reason, the oil price used as an instrumental variable in the demand estimation is converted to a 12-month moving average.

upper bounds of interval-identified marginal costs are estimated as:

$$\widehat{MC}_{jt}^{ED} = \underline{Z}^{-1}(Q_t - q_{jt}, Q_t, c_{et}). \tag{3.8}$$

In the case of entry deterrence, the marginal cost of potential entrant c_{et} must be known in advance to identify incumbents' marginal costs. Let the entrant's marginal cost be:

$$c_{et} = P_t \times 0.9. \tag{3.9}$$

Based on accounting data, the net profit margins of Nippon Light Metal[20] in the 1960s ranged from 4% to 6%. As noted in Section 3.2, to obtain a conservative (or wide) estimate of the identification region, I need to set low marginal costs for the entrant. Therefore, the marginal cost of a potential entrant is set lower than the level analogous to the incumbents' accounting unit cost.[21]

Depending on the form of the demand function specified, the function for estimating the upper bounds,$\underline{Z}^{-1}(.)$, can not be calculated explicitly. Therefore, in this study, the marginal costs are calculated numerically using the method described in Appendix A.3. Finally, when perfect competition is assumed to describe the aluminum industry, marginal costs can be identified and estimated as:

$$\widehat{MC}_{jt}^{P} = P_t. \tag{3.10}$$

Testing method Using the different marginal cost estimated by equations (3.7), (3.8), and (3.10), the assumptions of firm conduct can be tested. Pair-wise model selection tests for nonnested models originally developed by Vuong (1989) and further extended by Rivers and Vuong (2002) are beneficial. The tests are designed to determine which of the two models pair-wisely compared is appropriate in explaining the data. A distinctive feature of the test is that both models pair-wisely compared can be misspecified. Furthermore, while Vuong (1989) formalized model selection tests based on the likelihood of a model as a criterion, Rivers and Vuong (2002) enables a test based on a broad class of criterion

[20]Nippon Light Metal was the only firm specializing in aluminum in the 1960s.

[21]An alternative approach is to refer to engineering costs, which are calculated by building up the cost of raw materials. Tanaka (1969) estimates that the unit cost of aluminum production in 1969 (when the aluminum price was 205,000 yen) was 173,000 yen. Therefore, the cost represented by equation (3.9) is an intermediate cost falling between the costs inferred from the accounting and engineering data. Several specifications are examined, including (i)$c_{et} = 0.95 \times P_t$, (ii) $c_{et} = 0.85 \times P_t$, and (iii) c_{et} linearly decreases in time from 240 to 180. The third specification reflects the lowering of costs in response to improvements in electricity intensity, which are observed in the data. In all cases, the qualitative results concerning the test of firm conduct are the same as in the case in which equation (3.9) is assumed.

functions, including the residual sum of squares or moment-based objective functions.

There are several approaches to the test, depending on the criterion function used in the test. Conduct testing literature using the Vuong-type model selection tests have relied mainly on a criterion function, such as a likelihood or residual sum of squares of an estimated marginal cost function (Gasmi et al., 1992; Bonnet and Dubois, 2010; Doi and Ohashi, 2019). The idea underlying the tests based on these criterion functions is detecting which estimated marginal costs are best correlated to variables that are likely to affect firms' marginal costs (Bonnet and Dubois, 2010). Conversely, Berry and Haile (2014) derive restrictions for empirically distinguishing firm conduct. They show that models describing oligopolistic competition are testable using an appropriate instrumental variable. Specifically, if the competition model employed to identify marginal costs is correct, identified cost shocks are independent of the instrument; however, this is not the case when the model is incorrect. Backus et al. (2021) propose using a moment-based criterion function in conduct testing on Rivers and Vuong (2002)'s framework. They also propose an optimal instrument when there are multiple instrument variables available. Here, the latter approach, which relies on instruments, is employed.

The criterion function employed here is represented for model h as:

$$Q_n^h(\hat{\beta}^h) = \left(\frac{1}{n} \sum_{jt} \hat{\epsilon}_{jt}^h Z_{jt} \right)^2,$$

where $\hat{\beta}^h$ is the set of estimated parameters in the cost function (3.6) under model h, $\hat{\epsilon}_{jt}^h$ is the residual of the estimation, and Z_{jt} is an instrument. The average electricity intensity for firms other than firm j is an appropriate instrument because a firm's electricity intensity only reflects the technological aspects of the firm and is not expected to correlate with the other firms' cost shocks. The criterion function corresponds to the GMM objective function with the moment condition of $E[\epsilon_{jt}^h Z_{jt}] = 0$.

Taking any two models h and h', the null hypothesis that the two models equally satisfy the moment condition can be tested. The Rivers and Vuong (2002)'s test statistic is given by:

$$T = \frac{\sqrt{n}(Q_n^h(\hat{\beta}^h) - Q_n^{h'}(\hat{\beta}^{h'}))}{\hat{\sigma}_n^{hh'}}, \tag{3.11}$$

where $\hat{\sigma}_n^{hh'2}$ is the estimator of the asymptotic variance of the difference in the criterion functions. Because the specifications of our econometric models are nonnested, the test

statistic has a standard normal distribution under the null hypothesis. Therefore, it is possible to select a better model by comparing the value of the statistic with critical values of the standard normal distribution. Because the criterion function (3.11) is a lack-of-fit criterion, the null is rejected in favor of model h rather than h', if the test statistic T is smaller than -1.96 in the test with the size of $\alpha = 0.05$.

3.4.2 Data

Most of the data for this study are sourced from the *Yearbook of Aluminum Smelting*[22], which was issued annually from 1948 to 1985, and distributed only to divisions in MITI and organizations associated with the light metal business.

The yearbook provides useful monthly plant-level information on production, shipments, and raw material consumption, including electricity use. Because the yearbook includes industry-level total shipment values and volume information, the average aluminum shipment price data can be calculated by dividing the total shipment values by the total shipment volumes. The import data on bauxite and primary aluminum are drawn from the *Trade Statistics of Japan* from the Ministry of Finance. The oil price used in the analysis is the West Texas Intermediate crude oil price, which is converted into yen using monthly average yen-dollar rates. The total floor area of buildings on which construction had commenced is sourced from *the Survey of Building Construction Work Started*. All price variables are deflated by an industry deflator (the Corporate Goods Price Index in nonferrous metal products) in constant 1970 Japanese yen.

Month-level data from January 1955 to December 1980 (312 months) were used for the empirical analysis, although the yearbook provides data from 1950 to 1985. I confine the sample period for the empirical analysis for several reasons. First, I use data from 1955 onward because this was the year in which aluminum production in Japan recovered to its prewar level. This also excludes the Korean War (1950–1953) from the analysis, which significantly and unusually affected Japanese aluminum demand. Second, I end the period of analysis in 1980 owing to concerns regarding price data credibility after 1980. The yearbook provides price information other than the shipment price, which is used in the empirical analysis. Prices surveyed by several institutions are listed in the yearbook on a monthly basis. Although the surveyed price data moves in the same way as shipping price data until 1980, the surveyed price data show a downward trend despite the shipment price remaining high after 1980. Therefore, I only used data up to 1980 for the analysis. Table 3.2 provides descriptive statistics on each variable.

[22]The yearbook is called "Aluminum Seiren Kogyo Tokei Nenpo" in Japanese. The Japanese Aluminum Association provided the author with copies of the yearbook.

Table 3.2: Summary statistics

variables	unit	n	mean	sd	min	max
production	thousand tons	312	46.42	34.65	3.81	104.24
import	thousand tons	312	16.35	18.99	0.00	89.15
floor	milion m^2	312	12.07	6.60	2.13	26.34
eunit	MWh per ton	312	17.46	1.55	14.89	21.50
price	thousand JPY per ton	312	268.75	39.65	186.53	332.50
oil price	thousand JPY per barrel	312	1.87	0.95	0.90	5.62
bauxite price	thousand JPY per ton	312	4.83	1.50	2.11	10.71
prodF	thousand tons	1313	11.03	7.31	0.21	28.31
eunitF	MWh per ton	1313	17.16	2.23	12.63	61.11

Note: The variables 'floor' and 'eunit' mean 'total floor area of buildings on which construction had commenced' and 'electricity intensity', respectively. The variables 'prodF' and 'eunitF' represent firm-level production quantity and electricity intensity, respectively.

3.4.3 Results

Demand estimation Table 3.3 shows the estimation results of the demand function (3.5). The demand equation is estimated using ordinary least squares (OLS) and 2SLS. The first and second columns in the table show the estimation results for 2SLS and OLS, respectively. The third column presents the result of the first-stage regression of the 2SLS estimation. The estimated price coefficients have the expected signs and statistical significance in the 2SLS estimation. The results of the 2SLS estimation suggest that the price elasticity of aluminum demand is low ($\hat{\alpha} = -0.338$ in column 1). The estimate of the elasticity is similar to that estimated in a previous study; Boyd et al. (1995) estimate elasticity of -0.21 on average during the period 1965–1988 for the US aluminum industry. The estimate of the coefficient for the demand shifter, the total floor area of buildings on which construction had commenced, also shows the expected sign and statistical significance. The 2SLS estimation results are employed for the following cost function estimation and tests of firm conduct.

Cost and cost function estimation Using the estimation results of the demand function, each firm's marginal costs under the different assumptions of firm conduct are estimated.[23] Figure 3.3 shows the estimated marginal costs until 1974. The dashed, solid, and dotted lines represent marginal costs estimated under the assumption of the Cournot competition, entry-deterrence, and perfect competition models, respectively. When the Cournot

[23] Although month-level data are used to estimate marginal costs, the values of marginal costs are very similar even when I aggregate the month-level data into quarter-level.

Table 3.3: Demand estimates

	IV	*OLS*	*F.S.*
	(1)	(2)	(3)
price	-0.338^{**}	-0.079	
	(0.139)	(0.086)	
floor (M.A.)	1.020^{***}	1.138^{***}	0.131
	(0.089)	(0.078)	(0.085)
eunit			0.588^{**}
			(0.243)
oil price (M.A.)			0.364^{***}
			(0.063)
bauxite price			0.235^{***}
			(0.045)
Observations	312	312	312
R^2	0.989	0.990	0.756
Adjusted R^2	0.989	0.989	0.743
Residual S. E.	0.123	0.119	0.077

Note: The dependent variable is demand, which is calculated as the sum of domestic production and import in columns (1) and (2), while the dependent variable is the aluminum price in column (3) since the column shows the first stage regression of 2SLS estimation. All three specification includes a linear time trend and month fixed effects, while the estimated coefficients of them are removed from the table. For the floor variable, because there appear to be delays in the effect of it on aluminum demand, as seen in Figure 3.1, the 12-month moving averages are used. Due to a potential delayed effect of oil price on smelters' production cost, the oil prices are transformed to the 12-month moving averages. All dependent and independent variables except the time trend and the month fixed effects are transformed into the logarithmic form. Heteroskedasticity and serial correlation robust Newey-West standard errors are in parenthesis. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

competition is assumed, the more firms produce, the lower the identified marginal cost becomes. The figure shows that this is also the case when the entry-deterrence model is assumed: Nippon Light Metal held a high market share in the 1950s and 1960s, and the marginal costs of the firm are estimated to be lower than those of the other firms in the Cournot and entry-deterrence models.

To test the models, the marginal cost functions represented by equation (3.6) are estimated using two different samples. One sample includes data for the period before the 1973 oil crisis (i.e., from January 1955 to December 1973), whereas the other includes data after the shock (i.e., from January 1974 to December 1980). As seen in Section 3.3, in the first period, the incumbent firms were likely to be exposed to entry threats and, hence, might have attempted to deter entry. Conversely, after the 1973 oil shock, entry threats disappeared as a result of the reduced profitability of the industry.

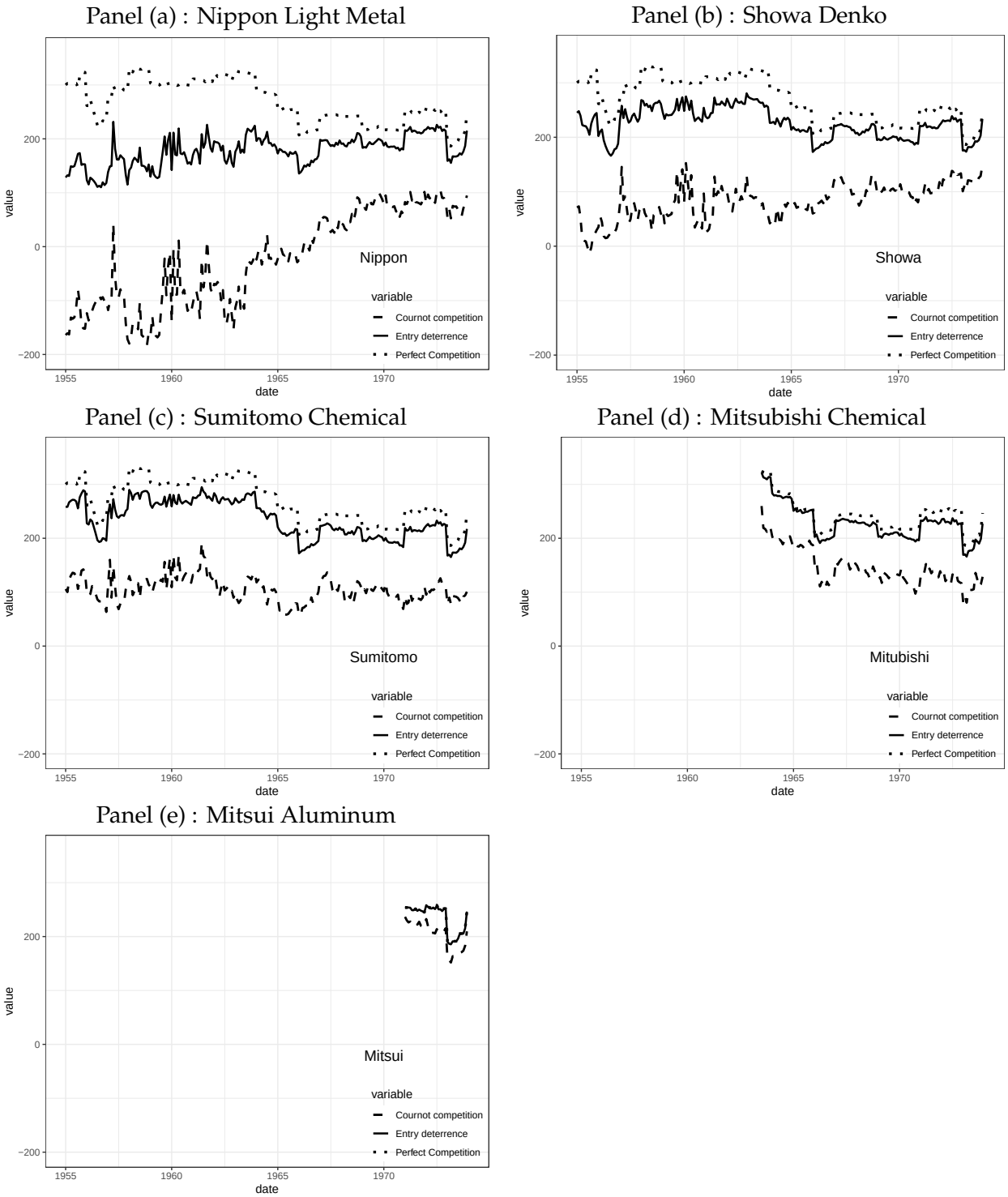
Table 3.4: Cost function estimates

	Dependent variable:				
	$\widehat{MC}^C$	$\widehat{MC}^{ED}$	$\widehat{MC}^P$	$\widehat{MC}^C$	$\widehat{MC}^P$
	(1)	(2)	(3)	(4)	(5)
bauxite price	1.961	7.734***	9.426***	11.419***	29.557***
	(1.247)	(1.521)	(1.608)	(3.488)	(1.400)
eunitF	1.440	4.452***	5.521***	0.344*	0.267***
×oil price (M.A.)	(1.504)	(0.520)	(0.619)	(0.208)	(0.080)
Observations	846	846	846	467	467
R^2	0.714	0.645	0.829	0.805	0.590
Adjusted R^2	0.708	0.637	0.825	0.797	0.573
Residual S.E.	45.458	23.328	16.834	23.542	23.735
Sample		Before		After	

Note: The dependent variables are the marginal costs identified under the different identification assumptions of competition. All specifications include a linear time trend, month fixed effects, and firm fixed effect as explanatory variables, while the estimated coefficients are omitted from the table. Due to a potential delayed effect of oil price on smelting production cost, the oil prices are transformed to 12-months moving averages. Columns (1), (2), and (3) are estimated using the sample period before the 1973 oil crisis, while columns (4) and (5) use the period after the 1973 oil crisis. Standard errors are clustered by firm and shown in parenthesis. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 3.4 shows the cost function estimation results. Columns (1), (2), and (3) are estimated employing the pre-oil-shock data and using the marginal cost estimated under the assumptions of Cournot, entry deterrence, and perfect competition, respectively. Columns

Figure 3.3: Identified marginal costs under the assumptions of three competing models



(4) and (5) are estimated employing the post-oil-shock data and using the marginal cost estimated under the assumptions of Cournot and perfect competition, respectively.

To interpret the estimated coefficients, it is beneficial to introduce engineering and chemical formulas that convert the raw materials, crude oil and bauxite, into the product, aluminum. The estimated cost function includes the bauxite price and the product of the oil price and electricity intensity as explanatory variables. First, β_0, the coefficient of the bauxite price, identifies how much bauxite is used to produce one ton of aluminum. Because about 4 tons of bauxite are consumed to produce 1 ton of aluminum, β_0 is expected to be close to 4. Second, β_1, the coefficient on the product term, identifies how much crude oil is needed to produce 1 MWh of electricity. To understand the interpretation of the coefficient, recall that electricity is needed to smelt aluminum and that crude oil is burned to generate electricity. Because $\beta_1 W_{jt}$ is equal to the marginal and unit cost of oil to produce 1 ton of aluminum, the following decomposition reveals why β_1 identifies the oil intensity for the generation of 1 MWh of electricity.

$$
\begin{aligned}
\beta_1 W_{jt} &= \text{unit cost of oil (thous. yen / ton)} \\
&= \text{oil intensity (barrels / ton)} \\
&\qquad \times \text{oil price (thous. yen / barrel)} \\
&= \text{oil intensity for electricity (barrels / MWh)} \times \text{electricity intensity (MWh / ton)} \\
&\qquad \times \text{oil price (thous. yen / barrel)},
\end{aligned}
$$

where the oil intensity for electricity represents how much crude oil is used to produce 1 unit of electricity. According to several energy-related statistics, 1.506 barrels of crude oil enables the generation of 1 MWh of electricity. Therefore, β_1 is expected to be estimated at 1.506.[24]

[24]The conversion formula is based on modern technology, and there are two assumptions behind the formula. Burning fuel such as crude oil or gas releases thermal energy. How much energy the burned fuel produces depends on the composition of the imported crude oil. The Agency for Natural Resources and Energy, a division in the Ministry of Economy, Trade, and Industry, has established standard gross calorific values for various energy sources to be used in energy-related statistics. It estimates that 1 liter of crude oil enables the generation of 38.26 MJ of thermal energy (Agency for Natural Resources and Energy, 2020). The standard values are revised every few years; however, the values for crude oil remain almost the same. Furthermore, not all of the thermal energy generated is converted into electricity. The formula assumes that 9,370 joules of thermal energy are required to use 1 Wh of electricity (Agency for Natural Resources and Energy, 2020). This means that 38.4% of the generated thermal energy is consumed as electricity because 1 Wh equals 3,600 joules if the loss is zero. How much thermal energy is transferred as electricity at the point of consumption is affected by several factors, including the efficiency in generating and transmitting electricity. Thermal efficiency, a measure of the performance of a generator, has improved from about 30% in the 1960s to about 40% today in Japan (The Federation of Electric Power Companies of Japan, each year). However, the improvement has not been sufficient to distort the interpretation of the coefficients.

Both β_0 and β_1 are estimated with the economically correct signs in Table 3.4, while the estimated values vary depending on the assumption on firm conduct and the sample period. If model selection was based on the values of estimated coefficients, a model with a $\hat{\beta_0}$ close to four and a $\hat{\beta_1}$ close to 1.506 would be selected. Therefore, the Cournot and entry-deterrence models may be selected in the pre-oil-shock period and the Cournot model may be selected in the post-oil-shock period.

Model selection test Employing the residuals of the cost function estimation and the instrumental variable Z_{jt}, the average electricity intensity for firms other than firm j at time t, I perform the model selection test proposed by Rivers and Vuong (2002). I perform not only the test employing the GMM objective function as a criterion but also the test for which the criterion function is the residual sum of squares (denoted as RSS). Table 3.5 reports the results from the tests. The upper half, panel (a), uses the GMM objective function, whereas the bottom half, panel (b), uses the RSS as a criterion. The first and second columns display the results employing the sample before the 1973 oil crisis and the third column reports the test employing the sample after the 1973 oil crisis. Because both are lack-of-fit criterion functions, negative values of the test statistics mean that the model in a row displays a better fit than the model in a column.

For the pre-oil-shock period, the table shows that the entry-deterrence model better fits with the data than does the Cournot competition model for both criteria, with statistical significance. When the entry-deterrence and perfect competition models are compared, the result of the test differs depending on which of the two criteria is adopted. Specifically, the GMM criterion slightly favors the entry-deterrence model, whereas the RSS criterion strongly favors the perfect competition model. The result of the two tests employing the pre-oil-crisis sample can be summarized as follows. First, the GMM criterion identifies the entry-deterrence model as the best model, whereas the RSS criterion identifies the perfect competition model as the best model.

For the post-oil-shock period, the result of the test shows that the Cournot competition model better fits with the data than does the perfect competition model in terms of both criteria, although those are not statistically significant.

Therefore, the testing results suggest that the 1973 oil shock changed the Japanese aluminum smelting industry from an environment in which the threat of entry prevailed and incumbents attempted to deter entry, to an environment where Cournot competition among incumbents prevails in the absence of entry threats. This conclusion is consistent with the historical fact that several companies ceased their efforts to enter the industry after the 1973 oil shock.

Table 3.5: Testing results

Panel (a) Criterion : GMM

Sample		Before		After
model h/h'		(ii) Entry Deterrence	(iii) Perfect Competition	(iii) Perfect Competition
(i)	Cournot Competion	2.70	2.25	−1.61
(ii)	Entry Deterrence	–	−1.12	–

Panel (b) Criterion : RSS

Sample		Before		After
model h/h'		(ii) Entry Deterrence	(iii) Perfect Competition	(iii) Perfect Competition
(i)	Cournot Competion	18.52	17.50	−0.25
(ii)	Entry Deterrence	–	9.27	–

Note: Panel (a) lists the values of model selection test statistics with GMM criterion function based on moment restriction, while panel (b) relies on RSS as a criterion function. Since both criterion functions used in panel (a) and (b) are a lack-of-fit criterion, a negative value suggests the model in the row is better fitted than models in the column. Since I do not estimate marginal cost function under the assumption of entry deterrence model after the 1973 oil crisis, only the test which compares the Cournot and perfect competition models are conducted using the sample after the 1973 oil crisis.

3.5 Conclusion

In this study, I proposed a structural model of noncooperative entry deterrence. I show that the marginal costs of incumbents are interval-identified given the marginal cost of an entrant. Furthermore, using the upper bounds on the interval-identified marginal costs, I conduct a model selection test and show that the entry-deterrence model better explains the data for the Japanese aluminum industry facing entry threat than does the Cournot model with no entry threats. In addition, I point out a caveat of using the upper bound, which is that it assumes that the equilibrium arises where the incumbents are mostly affected by the entry threat.

Finally, I note two limitations of this study. First, the entry-deterrence model essentially involves a static two-stage game. In the model, incumbents and a potential entrant only take into account their current profit and, therefore, the incumbents attempt to deter a potential entrant's "Hit and Run" entry. However, in the real world; both incumbents and the entrant take into account not only their current profit but also their future profit when determining their strategic decisions. Therefore, a dynamic model would be more appropriate to describe the industry. However, the model is a static one and abandons any dynamic aspects.

The effects of introducing dynamics may be imagined. Sweeting et al. (2020) extend a two-stage limit pricing entry-deterrence model to allow for any finite number of periods larger than two. They show that because the incentive to deter entry becomes larger than that in the two-stage game, their extended limit pricing model can explain a larger price decline to deter entry. The result of Sweeting et al. (2020) may suggest a consequence of introducing dynamics into the Gilbert and Vives (1986) model, If, like their results, the introduction of dynamics increased the incentive to deter entry, an entry-deterring equilibrium would occur even at high marginal costs and then higher upper bounds on marginal costs might be identified.

Second, marginal cost is interval-identified. There are two reasons for this: (i) the difficulty of identifying where the limit output Y specifically lies within the interval $[X_C, \overline{Y}]$, and (ii) the existence of multiple equilibria. Because the data do not indicate where the limit output Y is in $[X_C, \overline{Y}]$, the upper bounds on marginal costs correspond to the marginal costs identified under the equilibrium where all firms are just barely deterring entry. Furthermore, because there are multiple equilibria in the game, the knowledge of where Y is in between X^C and $\overline{Y}$ is not sufficient for the point-identification. To introduce uncertainty in entry costs and cross sections of markets with observables that affect the uncertainty may assist with the point-identification of marginal costs. Waldman (1987)

introduces uncertainty on the limit output Y in Gilbert and Vives (1986)'s model. In his model, because the first-order condition for incumbents' profit maximization is used to characterize the entry-deterring equilibrium, if the variables that affect the uncertainty associated with the entry cost are observable, the first-order condition may point identify the marginal cost. Furthermore, introducing cost uncertainty would be appropriate to describe real-world environments; that is, incumbents usually cannot perfectly predict the entry cost of a potential rival and the minimum output to achieve entry deterrence. Examination of the empirical validity of these approaches is an important subject that is reserved for future study.

A Appendix

The appendix provides a formal derivation of the best response function represented by equation (3.2), the proof of Proposition 2, and a method for numerical calculation of the upper bounds on the incumbents' marginal cost. The calculation method reveals why the entrant's marginal cost c_e should be set low to construct conservatively the identification region for the incumbents' marginal cost.

A.1 Derivation of the best response function $\phi_i(Z)$

Consider a game described in Section 3.2 and an optimization problem for incumbent i. Let Z be the total output excluding firm i and let $\phi_i(Z)$ be the best response. If there was no threat of entry, firm i would produce according to its Cournot best response $r(Z, c_i)$. Therefore, whenever $Z + r(Z, c_i) \geq Y$, the best response of firm i corresponds to its Cournot best response. Let $\overline{Z}(Y, c_i)$ satisfy the following equation:

$$r(Z, c_i) + Z = Y. \tag{3.12}$$

Because the Cournot best response function has a slope between -1 and 0, as revealed in following Lemma 1, the left-hand side of equation (3.12) is increasing in Z. Therefore, the solution of (3.12) is unique and the solution $\overline{Z}(Y, c_i)$ represents the minimum output level Z with which firm i can block entry by merely producing the Cournot optimal output. If the solution is negative, it is assumed that $\overline{Z}(Y, c_i) = 0$. In summary, if $Z \geq \overline{Z}(Y, c_i)$, the best response $\phi_i(Z)$ is equal to the Cournot optimal output $r(Z, c_i)$.

When $Z < \overline{Z}(Y, c_i)$, firm i cannot block entry by merely producing $r(Z, c_i)$ because $X_0 = r(Z, c_i) + Z$, which is the total output in the first stage, is less than Y. In this case, incumbent i has two options: deterring entry or allowing it. When firm i attempts to deter entry, it needs to produce more than $Y - Z$. Firm i has no incentive to produce an amount larger than $Y - Z$ for the purpose of entry deterrence because $Y - Z > r(Z, c_i)$ when $Z < \overline{Z}(Y, c_i)$. Hence, when firm i chooses to deter entry, it earns:

$$\overline{\pi}^{NE}(Z, Y, c_i) = (P(Y) - c_i)(Y - Z). \tag{3.13}$$

Here, $\overline{\pi}^{NE}(Z, Y, c_i)$ represents the value (or maximal profit) of the incumbent arising from deterring entry. Conversely, when entry is allowed, incumbent i plays the role of a Stackelberg leader. Let $s(Z, c_i, c_e)$ be the optimal output of firm i given that the potential entrant enters the market and produces optimally given a first-stage total output. When

incumbent i chooses to allow entry, it earns:

$$\overline{\pi}^E(Z, c_i, c_e) = (P(s(Z, c_i, c_e) + Z + r(s(Z, c_i, c_e) + Z, c_e)) - c_i)s(Z, c_i, c_e). \tag{3.14}$$

Here, $\overline{\pi}^E(Z, c_i, c_e)$ represents the value (or maximal profit) of the incumbent arising from allowing entry.

Firm i deters or allows entry by comparing the two values of (3.13) and (3.14). Firm i's optimal strategy involves a threshold value of Z; when Z is larger than the threshold, entry is deterred, otherwise, entry is allowed. First, the value of deterring entry represented by equation (3.13) is a linear decreasing function in Z. Second, as shown in Lemma 1, the value of allowing entry represented by equation (3.14) is strictly convex and decreasing in Z. Third, when $Z = \overline{Z}(Y, c_i)$, because $Y - Z$ corresponds to the Cournot best response, the value of deterring entry is larger than that of allowing entry. These three arguments guarantee that there exists a unique solution to the equation:

$$\overline{\pi}^{NE}(Z, Y, c_i) = \overline{\pi}^E(Z, c_i, c_e). \tag{3.15}$$

Let the solution to equation (3.15) be $\underline{Z}(Y, c_i, c_e)$ if it is positive and zero otherwise. When $\underline{Z}(Y, c_i, c_e) \leq Z < \overline{Z}(Y, c_i)$, the value of deterring entry is larger than that of allowing entry and thus incumbent i produces $Y - Z$. Conversely, when $0 \leq Z < \underline{Z}(Y, c_i, c_e)$, incumbent i allows entry and produces $s(Z, c_i, c_e)$. Therefore, $\underline{Z}(Y, c_i, c_e)$ represents the minimum output level Z at which incumbent i has an incentive to deter entry. In conclusion, the incumbent's best response function is represented by equation (3.2).

A.2 Proof of Proposition 2

The proposition states that the minimum level of the other firms' outputs required for firm i to deter entry is increasing in its marginal cost. To prove the proposition, several properties related to the two value functions in equations (3.13) and (3.14) and the response functions of $r(Z, c_i)$ and $s(Z, c_i, c_e)$ must be established. The following two lemmas summarize these properties.

Lemma 1 (Gilbert and Vives 1986) *The response functions $r(Z, c_i)$ and $s(Z, c_i, c_e)$ are decreasing in Z and have a respective slope between -1 and 0. The value of allowing entry $\overline{\pi}(Z, c_i, c_e)$ is strictly decreasing and convex in Z.*

Proof. The proof is almost the same as that in Gilbert and Vives (1986).[25] When $r(Z, c_i)$ is positive, it solves the first-order condition for x:

$$P(x + Z) - c_i + P'(x + Z)x = 0.$$

From the implicit function theorem, I have:

$$\frac{\partial r(Z, c_i)}{\partial Z} = -\frac{P' + P''x}{2P' + P''x}.$$

Because the inverse demand function is assumed to be concave, $P'' < 0$, the Cournot best response has a slope between -1 and 0. In the same manner, when $s(Z, c_i, c_e)$ is positive, it solves the first-order condition:

$$P(x + Z + r_e(x + Z)) - c_i + P'(x + Z + r_e(x + Z))(1 + r_e')x = 0, \tag{3.16}$$

where $r_e(.)$ is the abbreviation of $r(., c_e)$. The implicit function theorem produces:

$$\begin{aligned}\frac{\partial s(Z, c_i, c_e)}{\partial Z} &= -\frac{P'(1 + r_e') + P''(1 + r_e')(1 + r_e')x + P'r_e''x}{P'(1 + r_e') + P''(1 + r_e')(1 + r_e')x + P'(1 + r_e' + r_e''x)} \\ &= -\frac{(1 + r_e')(P' + P''(1 + r_e')x) + xP'r_e''}{(1 + r_e')(P' + P''(1 + r_e')x) + xP'r_e'' + (1 + r_e')P'}.\end{aligned}$$

Therefore, the response function $s(Z, c_i, c_e)$ has a slope between -1 and 0 by the assumption that the Cournot best response function $r(Z, c_i)$ is convex in Z, i.e., $r_e'' > 0$.

Finally, I show that the value of allowing entry represented by equation (3.14) is decreasing and convex in Z. Let π^E be the profit when entry is realized, i.e., $\pi^E = P(x + Z + r_e(x + Z))x - c_i x$. Because $\overline{\pi}^E(Z, c_i, c_e)$ is the value function of an incumbent as a Stackelberg leader, applying the envelope theorem gives:

$$\begin{aligned}\frac{\partial \overline{\pi}^E}{\partial Z} &= \frac{\partial \pi^E}{\partial Z}|x = s(Z, c_i, c_e) \\ &= P'(1 + r_e')x|x = s(Z, c_i, c_e) \\ &= sP'(1 + r_e') \\ &= -P(s + Z + r_e(s + Z)) + c_i.\end{aligned}$$

[25] Whereas Gilbert and Vives (1986) provide a proof under cost homogeneity, it is possible to give a proof under cost heterogeneity in exactly the same way. Gilbert and Vives (1986) do not show the comparative statics on the incumbents' marginal costs, which would be most relevant for the empirical analysis in this study, because they assume that marginal costs are zero for all firms.

The third and fourth lines show that the value function $\overline{\pi}^E$ is decreasing in Z. The fourth equality uses the first-order condition of (3.16). Therefore, $\frac{\partial^2 \overline{\pi}^E}{\partial Z^2} = -P'(1+s')(1+r_e')$. Because s' and r_e' is between -1 and 0, the second-order derivative is positive and $\overline{\pi}^E$ is convex in Z. ■

Lemma 2 *The two value functions $\overline{\pi}^{NE}(Z, Y, c_i)$ and $\overline{\pi}^E(Z, c_i, c_e)$ have partial derivatives as follows:*

$$\begin{aligned}
\frac{\partial \overline{\pi}^{NE}}{\partial c_i} &= -(Y - Z), \\
\frac{\partial \overline{\pi}^{NE}}{\partial Z} &= -(P(Y) - c_i), \\
\frac{\partial \overline{\pi}^{NE}}{\partial Y} &= P'(Y)(Y - Z) + P(Y) - c_i, \\
\frac{\partial \overline{\pi}^{E}}{\partial c_i} &= -s, \\
\frac{\partial \overline{\pi}^{E}}{\partial Z} &= sP'(1 + r_e'), \\
\frac{\partial \overline{\pi}^{E}}{\partial Y} &= 0,
\end{aligned}$$

where s and r_e are the abbreviations of $s(Z, c_i, c_e)$ and $r(s + Z, c_e)$, respectively, for notational ease.

Proof. The result for the partial derivatives of the value of deterring entry is straightforwardly calculated from equation (3.13). Applying the envelope theorem to the value of allowing entry gives:

$$\begin{aligned}
\frac{\partial \overline{\pi}^{E}}{\partial c_i} &= \frac{\partial \pi^E}{\partial c_i}\Big|_{x=s(Z,c_i,c_e)} \\
&= \frac{\partial}{\partial c_i}(P(Z + x + r_e(x + Z))x - c_i x)\Big|_{x=s(Z,c_i,c_e)} \\
&= -x\Big|_{x=s(Z,c_i,c_e)} \\
&= -s, \\
\frac{\partial \overline{\pi}^{E}}{\partial Y} &= \frac{\partial \pi^E}{\partial Y}(x)\Big|_{x=s(Z,c_i,c_e)} \\
&= 0.
\end{aligned}$$

The derivation of $\partial \overline{\pi}^E / \partial Z$ is in the proof of Lemma 1. ■

Proposition 2 (Repost) *When $\underline{Z}(Y, c_i, c_e) > 0$, $\underline{Z}(Y, c_i, c_e)$ is increasing in c_i.*

Proof. To guarantee that $\underline{Z}$ solves equation (3.15), take (Y, c_i, c_e) such that $\underline{Z} > 0$. Because $\underline{Z}$ solves equation (3.15), from the implicit function theorem, the following equation holds:

$$\begin{aligned}
\frac{\partial \underline{Z}}{\partial c} &= -\frac{\frac{\partial \overline{\pi}^{NE}}{\partial c_i} - \frac{\partial \overline{\pi}^{E}}{\partial c_i}}{\frac{\partial \overline{\pi}^{NE}}{\partial Z} - \frac{\partial \overline{\pi}^{E}}{\partial Z}} | Z = \underline{Z} \\
&= -\frac{-(Y - Z) - (-s)}{-(P(Y) - c_i) - sP'(1 + r_e')} | Z = \underline{Z} \\
&= \frac{Y - (s + Z)}{-(P(Y) - c_i) + P(s + Z + r(s + Z)) - c_i} | Z = \underline{Z} \\
&= \frac{Y - (s + Z)}{P(X^E) - P(Y)} | Z = \underline{Z} \\
&> 0,
\end{aligned}$$

where X^E represents the total output when entry is allowed, i.e., $X^E = s + s + r_e(s + Z)$. The third equality uses the first-order condition of a Stackelberg leader represented by equation (3.16). When $Z = \underline{Z}(Y, c_i, c_e)$, $Y > s + Z$ holds.[26] Since $\overline{\pi}^{NE} = (P(Y) - c_i) \times (Y - Z) = (P(X^E) - c_i) \times s = \overline{\pi}^{E}$ at $Z = \underline{Z}$, $P(X^E) > P(Y)$ and the last inequality hold. ■

A.3 A method to calculate the upper bounds on incumbents' marginal costs numerically; right-hand side of equation (3.4)

To calculate the right-hand side of equation (3.4), the function $\underline{Z}^{-1}(Y - x_i, Y, c_e)$ is required. However, the function may not be derived explicitly depending on the shape of the demand function specified and estimated in an empirical analysis. Even when the analytical calculation is difficult, equation (3.15) suggests an alternative approach for numerically calculating the upper bounds. Because incumbent i, which has the upper bound, is indifferent between deterring or allowing entry given the other firms' total output X_{-i}, the upper bound solves the following equation (3.17) for c_i:

$$\overline{\pi}^{E}(X_{-i}, c_i, c_e) = \overline{\pi}^{NE}(X_{-i}, X, c_i), \tag{3.17}$$

[26] The property that $Y > s(Z, c_i, c_e) + Z$ at $Z = \underline{Z}(Y, c_i, c_e)$ can be proved by contradiction. Assume that $Y \leq s(Z, c_i, c_e) + Z$ at $Z = \underline{Z}(Y, c_i, c_e)$. The assumption induces that $P(Y) > P(X^E) = P(s + Z + r_e(s + Z))$ at $Z = \underline{Z}$ because the values of deterring and allowing entry are equal at $Z = \underline{Z}$. When $Z > \underline{Z}$, the value of deterring entry exceeds that of allowing entry. Therefore, $\partial \overline{\pi}^{NE}/\partial Z > \partial \overline{\pi}^{E}/\partial Z$ at $Z = \underline{Z}$. This induces $\partial \overline{\pi}^{NE}/\partial Z > \partial \overline{\pi}^{E}/\partial Z \Leftrightarrow -(P(Y) - c_i) > -(P(X^E) - c_i) \Leftrightarrow P(Y) < P(X^E)$. This contradicts the property above and therefore $s(Z) < Y - Z$ when $Z = \underline{Z}(Y, c_i, c_e)$.

where X is the observable industry total output, which corresponds to Y. The left-hand side $\overline{\pi}^E(X_{-i}, c_i, c_e)$ is the value of a Stackelberg leader as a function of c_i, given the other firms' output X_{-i} and the entrant's marginal cost c_e. This function is represented as:

$$\overline{\pi}^E(X_{-i}, c_i, c_e) = (P(s(X_{-i}, c_i, c_e) + X_{-i} + r_e(s(X_{-i}, c_i, c_e) + X_{-i})) - c_i) \times s(X_{-i}, c_i, c_e).$$

The value function $\overline{\pi}^E$, the response function $s(.)$, and $r_e(.)$ are computable because (X_{-i}, c_e) is observed and $P(.)$ is estimated. Conversely, the right-hand side of equation (3.17) is the value of deterring entry as a function of c_i. This function is represented as:

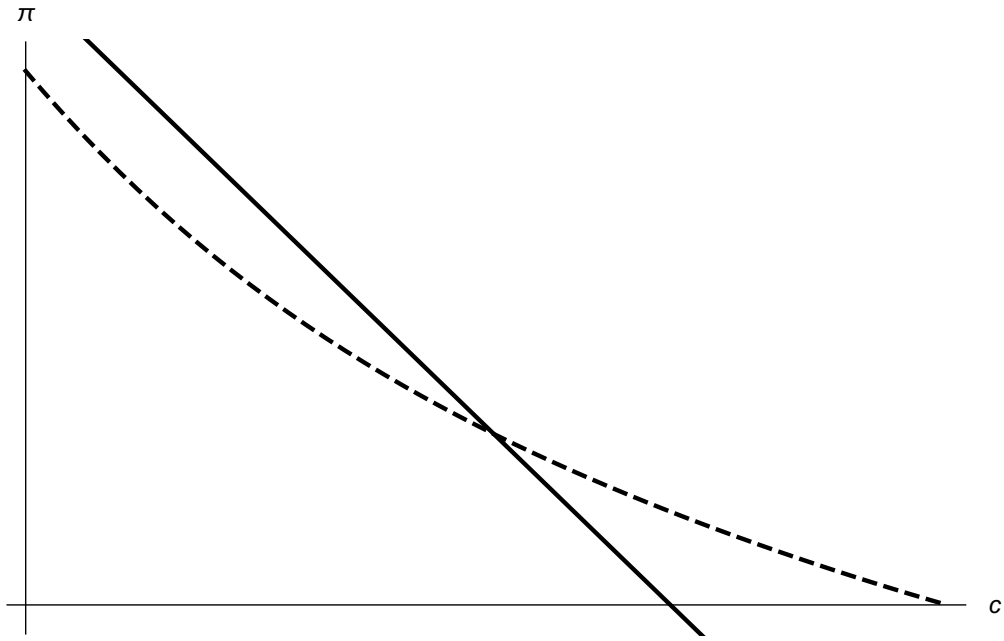
$$\begin{aligned}\overline{\pi}^{NE}(X_{-i}, X, c_i) &= (P(X) - c_i) \times (X - X_{-i}) \\ &= -x_i c_i + P x_i.\end{aligned}$$

This is also computable because (P, x_i) is observed. By computing the two value functions and calculating the intersection of the two, the upper bound of the marginal costs can be calculated.

Figure 3.4 shows an example of how to calculate the upper bound marginal costs. The horizontal axis represents marginal costs, and the vertical axis represents profits (values). The downward-sloping straight line represents the value of deterring entry for different c_i, given the other firms' output $Z = X_{-i}$ and the limit output $Y = X$. The curved dotted line represents the value of allowing entry for different c_i given the other firms' output $Z = X_{-i}$ and the entrant's marginal cost c_e. The intersection of the two functions is the upper bound on c_i.

In addition, the figure reveals that the entrant's marginal cost is set to the lowest value of a researcher's prior belief, i.e., $c_e = \underline{c}_e$, to construct the identification region on c_i conservatively. Because the value of allowing entry $\overline{\pi}^E(X_{-i}, c_i, c_e)$ is increasing in c_e, a decrease in c_e shifts the curved dotted line downward and the intersection of the two functions moves to the right: i.e., the upper bound on c_i increases.

Figure 3.4: Upper bound on c_i



Chapter 4

Conclusion

This dissertation presents two empirical studies which uncover the nature of competition of two Japanese industries: intercity coach and aluminum smelting. Since the data environments I face are different between the two studies, I apply different empirical methods in the two: the estimation of entry model for the intercity coach industry and the conduct testing for the aluminum smelting industry. Although the empirical approaches are distinct between the two, a common of the two studies is that (i) it uncovers the nature of competition of the respective industries and (ii) it becomes a starting point of further empirical studies of the two industries.

In Chapter 2, I estimate measures called the entry threshold ratio (ETR) and the adjusted ETR, whereby I show the existence of market competition in the Japanese intercity coach industry and the competitive effect of the deregulation that the industry has experienced. While the main result is to show the existence of market competition in the industry, I also show that the estimates of the adjusted ETRs gradually approach 1 as the number of firms in the market increases. This result is consistent with the implication of oligopolistic competition in IO, such as Cournot or (differentiated product) Bertland competition rather than that of perfect competition, therefore it gives support for assuming an oligopolistic model to study the industry through more sophisticated structural empirical models.

Research to be addressed in the future is to study the welfare implication of free entry because it is an important concern for the Japanese intercity coach industry, whose entry/exit regulations have been removed. Berry and Waldfogel (1999) study the welfare implications of free entry in the radio industry. In their study, it is assumed that the firms in the industry are competing in the Cournot manner. In order to conduct a study such as theirs, data on prices and volumes are needed, so it is not immediately feasible to conduct a similar analysis for the Japanese bus market. However, when more detailed data is

available, the results of this study will support the assumptions about the competition that are needed for a deeper analysis. In this sense, this study provides a starting point for the analysis of the Japanese bus market through structural econometric methods.

In Chapter 3, I test whether a specific model of competition can explain the Japanese aluminum smelting industry, and show that an entry deterrence model is consistent with the data before the 1973 oil shock and that the Cournot competition model is consistent with the data after the shock. This study also becomes a starting point for further econometric analysis using the data of the industry.

Japanese aluminum industry has experienced successive innovations in smelting technology. More specifically, the electricity intensity on average in the industry decreases 20,000 kWh/ton to 15,000 kWh/ton. In the literature of innovation, on the one hand, it has been suggested that the competitive environment influences innovation incentives and therefore innovation outcomes (Aghion et al., 2005). On the other hand, studies that examine the dynamic investment behavior of firms (ex., capacity investment/ scrapping, and innovation) often make assumptions about static competition (Igami, 2017). In general, an oligopoly model such as the Cournot competition is often assumed. The estimation result of this chapter suggests that a study that assumes the Cournot competition in the pre-oil crisis period will have biases in the innovation incentives of smelting firms.

The study also suggests that shocks such as the oil crisis can change the form of competition. In other words, in the case of the aluminum industry, the threat of entry was eliminated by the oil crisis, and I conclude that the industry moved from an entry-deterring equilibrium to a Cournot equilibrium. I hope that the two studies will serve as a stone cane for a more sophisticated empirical analysis of the two industries.

Bibliography

Adachi, T. 2005. "Expansion of the Direct Bus Network Connecting Haneda Airport with its Hinterland (Haneda Kuko Chokkou Basumou no Kakudai to sono Youin)." *Japanese Journal of Human Geography (Jinbun Chiri)* 57 (2) 173–194, (in Japanese).

Agency for Natural Resources and Energy. 2020. "Standard Gross Calorific Value and Carbon Emission Factors by Energy Sources (Enerugigenbestsu Hyojun Hatsunetsuryo/Tnanso Haisyutsu Keisu)." (in Japanese, available at: `https://www.enecho.meti.go.jp/statistics/total_energy/xls/stte_039.xlsx`).

Aghion, P., N. Bloom, R. Blundell, R. Griffith, and P. Howitt. 2005. "Competition and Innovation: An Inverted-U Relationship." *The Quarterly Journal of Economics* 120 (2) 701–728.

Ashiya, M. 2000. "Weak Entrants Are Welcome." *International Journal of Industrial Organization* 18 (6) 975–984.

Asker, J., and V. Nocke. 2021. "Collusion, Mergers, and Related Antitrust Issues." In *Handbook of Industrial Organization*, edited by Hortacsu, A., K. Ho, and A. Lizzeri Volume 5. 177–279, Elsevier.

Augustin, K., and M. Walter. 2010. "Operator Changes through Competitive Tendering: Empirical Evidence from German Local Bus Transport." *Research in Transportation Economics* 29 (1) 36–44.

Backus, M., C. Conlon, and M. Sinkinson. 2021. "Common Ownership and Competition in the Ready-To-Eat Cereal Industry." *National Bureau of Economic Research, Working paper*.

Bajari, P., H. Hong, and S. P. Ryan. 2010. "Identification and Estimation of a Discrete Game of Complete Information." *Econometrica* 78 (5) 1529–1568.

Bajari, P., and L. Ye. 2003. "Deciding Between Competition and Collusion." *Review of Economics and Statistics* 85 (4) 971–989.

Berry, S. T. 1992. "Estimation of a Model of Entry in the Airline Industry." *Econometrica* 60 (4) 889–917.

Berry, S. T., and P. A. Haile. 2014. "Identification in Differentiated Products Markets Using Market Level Data." *Econometrica* 82 (5) 1749–1797.

Berry, S. T., and P. C. Reiss. 2007. "Empirical Models of Entry and Market Structure." In *Handbook of Industrial Organization*, edited by Armstrong, M., and R. Porter Volume 3. 1845–1886, Elsevier.

Berry, S. T., and E. Tamer. 2006. "Identification in Models of Oligopoly Entry." In *Advances in Economics and Econometrics Theory and Applications, Ninth World Congress*, edited by Blundell, R., W. K. Newey, and T. Persson Volume 2. 46–85, Cambridge University Press.

Berry, S. T., and J. Waldfogel. 1999. "Free Entry and Social Inefficiency in Radio Broadcasting." *The RAND Journal of Economics* 30 (3) 397–420.

Bjorn, P. A., and Q. H. Vuong. 1984. "Simultaneous Equations Models for Dummy Endogenous Variables: A Game Theoretic Formulation with an Application to Labor Force Participation." *California Institute of Technology, Working paper*.

Blayac, T., and P. Bougette. 2017. "Should I Go by Bus? The Liberalization of the Long-Distance Bus Industry in France." *Transport Policy* 56 50–62.

Bonnet, C., and P. Dubois. 2010. "Inference on Vertical Contracts between Manufacturers and Retailers Allowing for Nonlinear Pricing and Resale Price Maintenance." *The RAND Journal of Economics* 41 (1) 139–164.

Boyd, R. G., C. Jung, and B. J. Seldon. 1995. "The Market Structure of the US Aluminum Industry." *Journal of Economics and Business* 47 (3) 293–301.

Bresnahan, T. F. 1982. "The Oligopoly Solution Concept Is Identified." *Economics Letters* 10 (1) 87–92.

Bresnahan, T. F. 1987. "Competition and Collusion in the American Automobile Industry: The 1955 Price War." *The Journal of Industrial Economics* 35 (4) 457–482.

Bresnahan, T. F., and P. C. Reiss. 1991a. "Entry and Competition in Concentrated Markets." *Journal of Political Economy* 99 (5) 977–1009.

Bresnahan, T. F., and P. C. Reiss. 1991b. "Empirical Models of Discrete Games." *Journal of Econometrics* 48 (1-2) 57–81.

Chernozhukov, V., H. Hong, and E. Tamer. 2007. "Estimation and Confidence Regions for Parameter Sets in Econometric Models1." *Econometrica* 75 (5) 1243–1284.

Ciliberto, F., and E. Tamer. 2009. "Market Structure and Multiple Equilibria in Airline Markets." *Econometrica* 77 (6) 1791–1828.

Cookson, J. A. 2017. "Anticipated Entry and Entry Deterrence: Evidence from the American Casino Industry." *Management Science* 64 (5) 2325–2344.

Corts, K. S. 1999. "Conduct Parameters and the Measurement of Market Power." *Journal of Econometrics* 88 (2) 227–250.

D'Haultfœuille, X., I. Durrmeyer, and P. Février. 2019. "Automobile Prices in Market Equilibrium with Unobserved Price Discrimination." *The Review of Economic Studies* 86 (5) 1973–1998.

Doi, N., and H. Ohashi. 2019. "Market Structure and Product Quality: A Study of the 2002 Japanese Airline Merger." *International Journal of Industrial Organization* 62 158–193.

Duarte, M., L. Magnolfi, and C. Sullivan. 2020. "Testing Firm Conduct." *Working paper,* (available at: `https://marco-duarte.github.io/publication/testing_firm_conduct/Testing_Firm_Conduct.pdf`).

Dürr, N. S., S. Heim, and K. Hüschelrath. 2016. "Deregulation, Competition, and Consolidation: The Case of the German Interurban Bus Industry." *Journal of Transport Economics and Policy (JTEP)* 50 (2) 164–188.

Dürr, N. S., and K. Hüschelrath. 2018. "Determinants of Entry in the Deregulated German Interurban Bus Industry." *Industrial and Corporate Change* 27 (3) 467–488.

Ellison, G., and S. F. Ellison. 2011. "Strategic Entry Deterrence and the Behavior of Pharmaceutical Incumbents Prior to Patent Expiration." *American Economic Journal: Microeconomics* 3 (1) 1–36.

Ericson, R., and A. Pakes. 1995. "Markov-Perfect Industry Dynamics: A Framework for Empirical Work." *The Review of Economic Studies* 62 (1) 53–82.

Fageda, X., and S. Sansano. 2018. "Factors Influencing Prices and Frequencies in the Interurban Bus Market: Evidence from Europe." *Transportation Research Part A: Policy and Practice* 111 266–276.

Feenstra, R. C., and J. A. Levinsohn. 1995. "Estimating Markups and Market Conduct with Multidimensional Product Attributes." *The Review of Economic Studies* 62 (1) 19–52.

Filippini, M., M. Koller, and G. Masiero. 2015. "Competitive Tendering versus Performance-Based Negotiation in Swiss Public Transport." *Transportation Research Part A: Policy and Practice* 82 158–168.

Gasmi, F., J. Laffont, and Q. H. Vuong. 1992. "Econometric Analysisof Collusive Behaviorin a Soft-Drink Market." *Journal of Economics & Management Strategy* 1 (2) 277–311.

Gayle, P. G., and Z. Luo. 2015. "Choosing between Order-of-Entry Assumptions in Empirical Entry Models: Evidence from Competition between Burger King and McDonald's Restaurant Outlets." *The Journal of Industrial Economics* 63 (1) 129–151.

Gayle, P. G., and X. Xie. 2018. "Entry Deterrence and Strategic Alliances." *Economic Inquiry* 56 (3) 1898–1924.

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

Gilbert, R., and X. Vives. 1986. "Entry Deterrence and the Free Rider Problem." *The Review of Economic Studies* 53 (1) 71–83.

Goto, A. 1988. "Japan: A Sunset Industry." In *The World Aluminum Industry in a Changing Energy Era*, edited by Peck, M. J. 90–120, Resources for the Future.

Heckman, J. 1974. "Shadow Prices, Market Wages, and Labor Supply." *Econometrica* 42 (4) 679–694.

Hsu, Y.-C., and X. Shi. 2017. "Model-selection Tests for Conditional Moment Restriction Models." *The Econometrics Journal* 20 (1) 52–85.

Igami, M. 2017. "Estimating the Innovator's Dilemma: Structural Analysis of Creative Destruction in the Hard Disk Drive Industry, 1981–1998." *Journal of Political Economy* 125 (3) 798–847.

Igami, M., and K. Uetake. 2019. "Mergers, Innovation, and Entry-Exit Dynamics: Consolidation of the Hard Disk Drive Industry, 1996–2016." *The Review of Economic Studies* 2672–2702.

Iwata, G. 1974. "Measurement of Conjectural Variations in Oligopoly." *Econometrica* 42 (5) 947–966.

Japanese Bus Association. 2016. "Japanese Bus Business (Nihon no Basu Jigyo)." (in Japanese).

Jia, P. 2008. "What Happens When Wal-Mart Comes to Town: An Empirical Analysis of the Discount Retailing Industry." *Econometrica* 76 (6) 1263–1316.

Kawai, K., and J. Nakabayashi. 2022. "Detecting Large-Scale Collusion in Procurement Auctions." *Journal of Political Economy*, Forthcoming.

Kim, D. W., and C. R. Knittel. 2006. "Biases in Static Oligopoly Models? Evidence from the California Electricity Market." *The Journal of Industrial Economics* 54 (4) 451–470.

Lau, L. J. 1982. "On Identifying the Degree of Competitiveness from Industry Price and Output Data." *Economics Letters* 10 (1) 93–99.

Lieberman, M. B. 1987. "Excess Capacity as a Barrier to Entry: An Empirical Appraisal." *The Journal of Industrial Economics* 35 (4) 607–627.

Mankiw, N. G., and M. D. Whinston. 1986. "Free Entry and Social Inefficiency." *The RAND Journal of Economics* 17 (1) 48–58.

Manski, C. 1988. *Analog Estimation Methods in Econometrics*. Chapman and Hall.

Manski, C. 1995. *Identification Problems in the Social Sciences*. Harvard University Press.

Matzkin, R. L. 2007. "Nonparametric Identification." In *Handbook of Econometrics*, edited by Heckman, J., and E. Leamer Volume 6. 5307–5368.

Mazzeo, M. J. 2002a. "Competitive Outcomes in Product-Differentiated Oligopoly." *The Review of Economics and Statistics* 84 (4) 716–728.

Mazzeo, M. J. 2002b. "Product Choice and Oligopoly Market Structure." *The RAND Journal of Economics* 33 (2) 221–242.

Miwa, H. 2016. *Aluminum Industry of Japan: The Rise and Decline in Aluminum Smelting Industry (Aruminium Seiren Gyo No Koryu to Suitai)*. Mie university press (Mie Daigaku Syuppan Kai), (in Japanese).

Mizuta, S. 2020. "Deregulation and Competition in Japanese Intercity Coach Industry." *Transportation Research Part A: Policy and Practice* 139 17–34.

MLIT. 2015. "Inter-Regional Travel Survey in Japan." (available at: `https://www.mlit.go.jp/seisakutokatsu/jyunryuudou/report_en/h17_report.pdf`).

Molinari, F. 2020. "Microeconometrics with Partial Identification." In *Handbook of Econometrics*, edited by Durlauf, S., L. Hansen, J. Heckman, and R. Matzkin Volume 7A. 355–486, North Holland.

Neo, K. 2003. "An Essay on Aluminium Smelting Industry. Especially on Half a Century of Japanese Smelting Industry - from the Birth through the Sudden Death (6) (Aruminum Sangyo Ron (6))." *Arutopia* 33 (3) 55–60, (in Japanese).

Nevo, A. 2001. "Measuring Market Power in the Ready-to-Eat Cereal Industry." *Econometrica* 69 (2) 307–342.

Newey, W. K., and K. D. West. 1987. "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55 (3) 703–708.

Nishiwaki, M. 2012. "Entry Model (Sannyu Moderu)." In *Handbook of Economic Analysis Used in Competition Policy- CPRC Handbook Series No.1- (Kyoso Seisaku de Tsukau Keizai Bunnseki Hanndobukku- CPRC Handobukku Sirizu No.1-)*, (in Japanese).

Ohashi, H. 2009. "Effects of Transparency in Procurement Practices on Government Expenditure: A Case Study of Municipal Public Works." *Review of Industrial Organization* 34 (3) 267–285.

Okumura, T., and E. Usui. 2014. "Concave-Monotone Treatment Response and Monotone Treatment Selection: With an Application to the Returns to Schooling: Treatment Response and Selection." *Quantitative Economics* 5 (1) 175–194.

Peck, M. J. ed. 1988. *The World Aluminum Industry in a Changing Energy Era*. Routledge.

Porter, R. H. 1983. "A Study of Cartel Stability: The Joint Executive Committee, 1880-1886." *The Bell Journal of Economics* 14 (2) 301.

Porter, R. H., and J. D. Zona. 1993. "Detection of Bid Rigging in Procurement Auctions." *Journal of Political Economy* 101 (3) 518–538.

Puller, S. L. 2009. "Estimation of Competitive Conduct When Firms Are Efficiently Colluding: Addressing the Corts Critique." *Applied Economics Letters* 16 (15) 1497–1500.

Rivers, D., and Q. H. Vuong. 2002. "Model Selection Tests for Nonlinear Dynamic Models." *The Econometrics Journal* 5 (1) 1–39.

Robbins, D. K., and P. R. White. 1986. "The Experience of Express Coach Deregulation in Great Britain." *Transportation* 13 (4) 359–384.

Sakai, H., and Y. Suzuki. 2011. "The Purpose of Hiving-off Strategy in the Private Bus Industry: Analysis of Relationship between Parent and Subsidiary company (Minkan Basujigyou ni okeru Bunsyaka sareta Soshikikeitai ni kansuru Ichikosastsu)." *Annual Report on Transportation Economics (Koutsugaku Kenkyu)* 54 145–154, (in Japanese).

Sakai, H., and Y. Takahashi. 2013. "Ten Years after Bus Deregulation in Japan: An Analysis of Institutional Changes and Cost Efficiency." *Research in Transportation Economics* 39 (1) 215–225.

Salvo, A. 2010. "Inferring Market Power under the Threat of Entry: The Case of the Brazilian Cement Industry." *The RAND Journal of Economics* 41 (2) 326–350.

Schaumans, C., and F. Verboven. 2014. "Entry and Competition in Differentiated Products Markets." *The Review of Economics and Statistics* 97 (1) 195–209.

Scheffler, R., K.-H. Hartwig, and R. Malina. 2013. "The Effects of Ownership Structure, Competition, and Cross-Subsidisation on the Efficiency of Public Bus Transport: Empirical Evidence from Germany." *Journal of Transport Economics and Policy* 47 (3) 371–386.

Seim, K. 2006. "An Empirical Model of Firm Entry with Endogenous Product-Type Choices." *The RAND Journal of Economics* 37 (3) 619–640.

Shi, X. 2015. "Model Selection Tests for Moment Inequality Models." *Journal of Econometrics* 187 (1) 1–17.

Smiley, R. 1988. "Empirical Evidence on Strategic Entry Deterrence." *International Journal of Industrial Organization* 6 (2) 167–180.

Snider, C. 2009. "Predatory Incentives and Predation Policy: The American Airlines Case." *University of California at Los Angeles, Working paper*.

Sudhir, K. 2001. "Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer." *Marketing Science* 20 (3) 244–264.

Suslow, V. Y. 1986. "Estimating Monopoly Behavior with Competitive Recycling: An Application to Alcoa." *The RAND Journal of Economics* 17 (3) 389–403.

Sweeting, A., J. W. Roberts, and C. Gedge. 2020. "A Model of Dynamic Limit Pricing with an Application to the Airline Industry." *Journal of Political Economy* 128 (3) 1148–1193.

Takahashi, Y. 2004. "The Purpose of and the Trends in Demerger by Bus Companies (Basu Jigyo ni okeru Bunsyaka no Igi to Doko)." *Journal of Public Utility Economics (Koeki Jigyo Kenkyu)* 56 (2) 61–68, (in Japanese).

Takahashi, Y. 2015. "Estimating a War of Attrition: The Case of the US Movie Theater Industry." *American Economic Review* 105 (7) 2204–2241.

Tamer, E. 2003. "Incomplete Simultaneous Discrete Response Model with Multiple Equilibria." *The Review of Economic Studies* 70 (1) 147–165.

Tanaka, H. 1969. *Current Status and Issues in the Aluminum Industry (Aruminiumu Kogyo No Genjo to Kadai)*. Japan Light Metal Association (Keikinzoku Kyokai), (in Japanese).

Tauchen, H., F. D. Fravel, and G. Gilbert. 1983. "Cost Structure of the Intercity Bus Industry." *Journal of Transport Economics and Policy* 17 (1) 25–47.

The Federation of Electric Power Companies of Japan. each year. "Electricity Statistics (Denryoku Tokei Jouhou)." (in Japanese, available at: `https://pdb.fepc.or.jp/pdb/%E3%83%87%E3%83%BC%E3%82%BF%E3%83%99%E3%83%BC%E3%82%B9%E4%B8%80%E8%A6%A7_%E9%9B%BB%E5%8A%9B%E7%B5%B1%E8%A8%88%E6%83%85%E5%A0%B1`).

Tirole, J. 1988. *The Theory of Industrial Organization*. MIT Press.

Train, K. 2009. *Discrete Choice Methods with Simulation*. Cambridge University Press.

van de Velde, D. 2013. "Long-distance coach services in Europe." In *Regulating Transport in Europe*, edited by Finger, M., and T. Holvad 115–139, Edward Elgar Publishing.

Villas-Boas, S. B. 2007. "Vertical Relationships between Manufacturers and Retailers: Inference with Limited Data." *The Review of Economic Studies* 74 (2) 625–652.

Vives, X. 1999. *Oligopoly Pricing: Old Ideas and New Tools*. MIT Press.

Vuong, Q. H. 1989. "Likelihood Ratio Tests for Model Selection and Non-Nested Hypotheses." *Econometrica* 57 (2) 307–333.

Waldman, M. 1987. "Noncooperative Entry Deterrence, Uncertainty, and the Free Rider Problem." *The Review of Economic Studies* 54 (2) 301–310.

White, P. R. 2018. "Prospects in Britain in the Light of the Bus Services Act 2017." *Research in Transportation Economics* 69 337–343.

White, P. R., and D. K. Robbins. 2012. "Long-Term Development of Express Coach Services in Britain." *Research in Transportation Economics* 36 (1) 30–38.

Williams, J. W. 2012. "Capacity Investments, Exclusionary Behavior, and Welfare: A Dynamic Model of Competition in the Airline Industry." *SSRN Electronic Journal*.

Wollmann, T. G. 2018. "Trucks without Bailouts: Equilibrium Product Characteristics for Commercial Vehicles." *American Economic Review* 108 (6) 1364–1406.