Competitive Structure of Japanese Automobile Market

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Abstract

This study examines competitive structure of the automobile market in Japan. We extend the framework proposed by Berry and Waldfogel (1999) so that it can handle differentiated product market such as the one for automobile and investigate if the current product mixes of these Japanese automobile manufacturers is optimal in the sense that any introduction of a new product or any removal of an existing product is

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product will lead to a reduction of profit or market share or both for the manufacturers.

1 Introduction

This study examines the competitive structure of the automobile market in Japan. Specifically, we focus on the role of the number of products each firm chooses to retain in the market. Firms may wish to introduce new products to the market in order to create a new segment and to increase their own profit. They may wish to retire some of their products when they are not profitable. On the other hand, they may decide to retain their product mix even if some of their products are not profitable to prevent other firms to enter into that segment. In a highly competitive market such as the automobile market in Japan, each firm ends up having its own product mix as a result of these games it chooses to play. In this paper, we incorporate the number of products as the firm’s strategic tool into the simultaneous estimation of demand and supply to uncover its role in Japanese automobile market.

The number of automobiles sold in Japan declined from about 6.0 million in 1990 to 3.4 million in 2007—about 43% decrease in 17 years. One of the reasons is households’ decision to keep automobiles longer. According to a study of automobile market for 2007 fiscal year (2008), a new vehicle was kept for 6.2 years in 2001, but this number increased to 7.1 years in 2007. In addition, 54% of household kept the same automobiles for over 7 years and 15% for over 10 years.

On the other hand, the number of product models has not decreased nearly as much (see Figure 1). According to Draganska and Jain (2005), the expanding product models improves consumer surplus, so that the firm in-
creases market share. Firms strive to do this in vertical and horizontal ways. For instance, TOYOTA has been trying to target many income groups by providing them with the wide range of minivans in prices from SIENTA to ALPHARD (see Figure 2). This strategy of vertical segmentation involves price discrimination according to consumers’ willingness to pay for quality (Mussa and Rosen 1978, Moorthy 1984, and Horsky and Nelson 1992). On the other hand, two minivans NOAH and VOXY offered by TOYOTA in Japanese market are nearly identical in terms of basic specifications except for some pricey options but they are sold through different dealership networks. Obviously, this horizontal segmentation was devised partly to prevent TOYOTA’s customers from switching to its competitors (Klemperer 1995).

![Graph](image)

Figure 1: The relative number of automobiles sold as in Japan as well as the relative number of models (1991=100).

However introducing a new product model would possibly cannibalize some of its existing products. Bayus and Putsis (1999) find that product proliferation has a positive effect on demand, but Draganska and Jain (2005) note that excessive expansion of product models adversely affects the market share of that firm.

There are a number of studies to uncover the firms’ profitability and
identify the nature of competition. Bresnahan and Reiss (1987, 1990, 1991) provide an important idea on the distribution of the equilibrium number of firms in a market using game theoretic model. Especially, Bresnahan and Reiss (1991), while studying the relationship between the number of firms in a market, market size and the nature of competition among heterogeneous firms, show that the number of firms in an oligopolistic market varies with changes in demand and market competition. Their ideas made an important influence on the entry analysis. Berry (1992) analyzes the airline market focusing on the effect of an airline’s scale of operation on entry by an oligopoly entry model. He extends the models provided by Bresnahan and Reiss (1991) and Reiss and Spiller (1989) in order to take into account the more heterogeneous firms. The model enables estimating profit using firm specific variables. However, the model cannot be applied to differentiated goods market.

Berry and Waldfogel (1999) investigate free entry into the radio broadcasting using three primitives: the listening share function derived by a simple discrete-choice formulation for listeners’ choices; the demand for listeners that uses a simple constant elasticity specification for the inverse advertiser-
ing demand curve; the distribution of fixed costs, which helps to determine the observed number of firms. For the listning share function, they use a nested logit utility function to parameterize the degree to which stations offer unique, programming and follow Berry (1994) to estimate demand parameters. As for the demand for listeners, it is formulated so that, given a number of listeners, a station produces revenue by ”selling” these listeners to advertisers. They assume that there is a fixed number of advertising minutes sold per hour and that the price of a single advertisement sold by a station is proportional to its number of listeners. As a result, total revenue of a station is the market ad price per listener times the average number of listeners. They allow advertisers’ marginal willingness-to-pay for listeners to decline in the share of population listening to radio. For the the distribution of fixed costs, they assume that listeners are divided equally among stations, and fixed costs are equal across stations. As in Bresnahan and Reiss (1990), the assumption that fixed costs are equal for all firms leads naturally to the ”or-
dered probit” likelihood function. Those parameters in these three primitives are simultaneously estimated by generalized method of moments.

In this paper, we extend the framework proposed by Berry and Waldfogel (1999) so that it can handle differentiated product market such as the one for automobile and investigate If the current product mixes of these Japanese automobile manufacturers is optimal in the sense that any introduction of a new product or any removal of an existing product will lead to a reduction of profit or market share or both for the manufacturers.

This paper is organized as follows. In sections 2, we present econometric specification and the data are described in section 4. In section 3, we discuss the method of estimation. In section 5, we present results, and in section 6, we discuss implications of our findings and future research direction.
2 Econometric Specification

2.1 The Product Share Function

We use a simple discrete-choice formulation for consumers’ choices. We assume that there are $I$ consumers facing $J$ products in a market. Each consumer in the market chooses among a set of choices that includes all the product in the market and also includes the choice of not purchasing any of the product. We assume that a consumer first chooses a body type from sedan, station wagon, hatchback, coupe, minivan and SUV, and then chooses a vehicle within the body type. These body types are non-overlapping and we assume that each body type forms a nest. We use a nested logit utility function to parameterize the degree to which products offer unique benefit to each consumer.

The utility consumer $i$ obtains from product $j$ is denoted by

$$U_{ij} = \delta_j + \epsilon_{ij}$$

$$= x_j \beta - \alpha p_j + \xi_j + \epsilon_{ij},$$

where $\delta_j$ is the mean utility of purchasing a product $j$, $\epsilon_i = (\epsilon_{i1}, \ldots, \epsilon_{iJ})$, a vector of generalized extreme-value deviates with the parameter $\lambda_k$ being a measure of the degree of independence in unobserved utility among the products in nest $B_k$, is the idiosyncratic benefit of products $j = 1, \ldots, J$ for consumer $i$, a $(1 \times R)$ vector $x_j$ and $\xi_j$ are respectively the observed and unobservable (by econometrician) exogenous characteristics for product $j$, $p_j$ is its price to be determined in the model, $\beta$ and $\alpha$ are respectively a vector of parameters corresponding to the exogenous product characteristics $x_j$ and to the price $p_j$, both are assumed invariant across consumers. The utility of not purchasing anything or purchasing the outside good in nest $B_0$ is random and given only by the extreme value deviate $\epsilon_{i0}$, or the mean utility
level $\delta_0 = 0$ of the outside good is zero. The unobservable $\xi_j$ is assumed to be mean independent of the exogenous $x_j$. The generalized extreme-value formulation for the idiosyncratic benefit of products $j$ in nests $B_k$ gives rise to the model-calculated choice probability $s^e_{ij}$ for consumer $i$ for product $j$ and also its market share $s^e_{i0}$ as

$$s^e_{ij} = s^e_{i0}(\delta) = \frac{\exp \left( \delta_j / \lambda_k \right)}{\sum_{l=0}^{K} \left( \sum_{j \in B_k} \exp \left( \delta_j / \lambda_k \right) \right)^N},$$

where $\delta = (\delta_1, \ldots, \delta_J)$ is the mean utility vector of purchasing a product $j$, $j = 1, \ldots, J$. The statistic $1 - \lambda_k$ is a measure of correlation in unobserved utility among the alternatives in nest $k$, in the sense that as $\lambda_k$ rises, indicating less correlation, this statistic drops. Obviously the model-calculated choice probability $s^e_{i0}$ for the outside good and also its market share $s^e_{00}(\delta)$ is

$$s^e_{i0} = s^e_{00}(\delta) = \frac{1}{\sum_{l=0}^{K} \left( \sum_{j \in B_k} \exp \left( \delta_j / \lambda_l \right) \right)^N}.$$

The researcher can constrain the $\lambda_k$’s to be the same for all (or some) nests, indicating that the correlation is the same in each of these nests. To maintain the tractability of the entry model, we assume that the $\lambda_k$’s are the same for all nests.

The measure of consumers in a market is denoted by $M$. We assume that this number is observed as the population of a market. It is, for example, set to be equal to the number of households in the economy, (Berry, Levinsohn and Pakes 1995), but in general not equal to the total number of products sold, since consumers may choose outside goods, $j = 0$. Let $q_j$ represent observed output quantity of product $j$, then observed market share $s_j$ of product $j$ becomes $s_j = q_j / M$. The observed market share $s_0$ of outside good is then $s_0 = 1 - \sum_{j=1}^{J} q_j / M$. 

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At the true values of the parameters $\beta$, $\alpha$, and $\lambda$, the observed market shares $s_{j/B_t}$ and $s_{B_t}$ of product $j$ within nest $B_t$ and those of nest $B_t$ in the market respectively match the model-calculated market counterparts for $j = 1, \ldots, J$:

$$s_{j/B_t} = s_{j/B_t}^e(\delta),$$

$$s_{B_t} = s_{B_t}^e(\delta),$$

where $s_{j/B_t}^e(\delta)$ and $s_{B_t}^e(\delta)$ are the model-calculated shares of product $j$ within nest $B_t$ and those of nest $B_t$ in the market. As a result, we have

$$s_j = s_j^e(\delta),$$

for $j = 1, \ldots, J$ as well. These equalities between observed and estimated market shares with respect to $\delta$ will be exploited in estimation.

To estimate the parameters, $\beta$, $\alpha$, and $\lambda$, we follow the method in Berry (1994). Given the observed market share $s_j$ of product $j$, we can invert the nested logit market-share function to solve for each $\delta_j$ as a function of the parameter $\lambda$. The unobservable $\xi_j$ is then defined as

$$\xi_j = \delta_j(s_0, s_1, \ldots, s_J) - x_j\beta + \alpha p_j.$$

Berry (1994) shows that

$$\log(s_j^e(\delta)) - \log(s_j^e(\delta)) =$$

$$x_j\beta - \alpha p_j + (1 - \lambda) \log(s_{j/B_t}^e(\delta)) + \xi_j.$$

With (6.6) and (6.6), (6.7) is now

$$\xi_j = \log(s_j) - \log(s_0) - x_j\beta + \alpha p_j - (1 - \lambda) \log(s_{j/B_t}).$$

Given a vector of demand side instruments $z_d$ based on the exogenous data, a method of moments estimator can then be formed from the moment conditions:

$$E[\xi_j | z_d] = 0.$$
2.2 The Pricing Equation

We assume that the $F$ firms in a market, each of which produce some subset of the $J$ products, are price-setters and set prices of their products to maximize the profit from each of the product. The observed and unobservable (by econometrician) exogenous cost shifters are respectively denoted by a vector $\mathbf{w}_j$ and variable $\omega_j$ for product $j$. For product $j$, marginal cost is $C_j(\mathbf{w}_j, \omega_j, \gamma)$, where $\gamma$ is a vector of unknown parameters. We also assume that there is a fixed cost, $FC_j$, of manufacturing product $j$ that does not vary with the number of products produced. Profit $\pi_j(\delta, \mathbf{w}_j, \omega_j, \gamma)$ of product $j$ is

$$\pi_j(\delta, \mathbf{w}_j, \omega_j, \gamma) = (p_j^e - C_j(\mathbf{w}_j, \omega_j, \gamma)) \cdot M \cdot s_j^e(\delta) - FC_j,$$

(2.11)

where $p_j^e$ is the model-calculated price of product $j$ and $M$ denotes the market size. Taking partial derivative (2.11) with respect to price $p_j^e$ gives

$$\frac{\partial \pi_j(\delta, \mathbf{w}_j, \omega_j, \gamma)}{\partial p_j^e} = M \left[ s_j^e(\delta) + \left\{ p_j^e - C_j(\mathbf{w}_j, \omega_j, \gamma) \right\} \cdot \frac{\partial s_j^e(\delta)}{\partial p_j^e} \right] = M \left[ s_j^e(\delta) - \alpha \left\{ p_j^e - C_j(q_j, \mathbf{w}_j, \omega_j, \gamma) \right\} \cdot \frac{\partial s_j^e(\delta)}{\partial p_j^e} \right].$$

(2.12)

Assuming the existence of a pure-strategy interior Nash equilibrium, the price vector satisfies the usual first-order conditions from (2.12) as

$$p_j^e = C_j(\mathbf{w}_j, \omega_j, \gamma) + \frac{1}{\alpha} \cdot \frac{s_j^e(\delta)}{\partial s_j^e(\delta)/\partial \delta_i}.$$

(2.13)

We assume that the marginal cost $C_j(\mathbf{w}_j, \omega_j, \gamma)$ is a function of the observed and unobservable exogenous cost shifters as in

$$C_i(\mathbf{w}_j, \omega_j, \gamma) = \bar{c}_j(q_j, \mathbf{w}_j, \gamma) + \omega_j = \mathbf{w}_j \cdot \gamma + \omega_j.$$

(2.14)

With (2.14), the pricing equation becomes

$$p_j^e = \mathbf{w}_j \cdot \gamma + \frac{1}{\alpha} \cdot \frac{s_j^e(\delta)}{\partial s_j^e(\delta)/\partial \delta_j} + \omega_j.$$

(2.15)
Under nested logit model (2.3) with $\lambda_k = \lambda$, the partial derivative $\partial s_j^e(\delta) / \partial \delta_j$ in (2.15) with respect to $\delta_j$ is shown in Berry (1994) to be

$$\frac{\partial s_j^e(\delta)}{\partial \delta_j} = \frac{\partial}{\partial \delta_j} \left[ \frac{\exp(\delta_j / \lambda) \left\{ \sum_{j \in B_h} \exp(\delta_j / \lambda) \right\}^{\lambda - 1}}{\sum_{t=0}^{K} \left\{ \sum_{j \in B_t} \exp(\delta_j / \lambda) \right\}^{\lambda}} \right] = \frac{s_j^e(\delta)}{\lambda} \left\{ 1 + (\lambda - 1)s_{j/B_h}^e(\delta) - \lambda s_j^e(\delta) \right\}. \quad (2.16)$$

From (2.16), the model-calculated pricing equation (2.15) under nested logit becomes

$$p_j^e(\alpha, \beta, \lambda, \gamma) = w_j \cdot \gamma + \frac{\lambda}{\alpha \cdot \left\{ 1 + (\lambda - 1)s_{j/B_h}^e(\delta) - \lambda s_j^e(\delta) \right\}} + \omega_j. \quad (2.17)$$

At the true values of the parameters $\alpha$, $\beta$, $\lambda$, and $\gamma$, the observed prices $p_j$ of product $j$ match the model-calculated market prices $p_j^e(\alpha, \beta, \lambda, \gamma)$ for $j = 1, \ldots, J$:

$$p_j = p_j^e(\alpha, \beta, \lambda, \gamma). \quad (2.18)$$

These equalities between observed and model-calculated prices will be exploited in estimation.

With (2.6), (2.6), and (2.18), the unobservable $\omega_j$ is from (2.17),

$$\omega_j = p_j - w_j \cdot \gamma - \frac{\lambda}{\alpha \cdot \left\{ 1 + (\lambda - 1)s_{j/B_h}^e(\delta) - \lambda s_j^e(\delta) \right\}}. \quad (2.19)$$

The term $\omega_j$ is an unobservable shock to product prices that is assumed to be mean independent of the exogenous data. Given a vector of supply side instruments $z_s$, based on the exogenous data, a method of moments estimator can then be formed from the moment conditions:

$$E [\omega_j | z_s] = 0. \quad (2.20)$$

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2.3 Instruments

Assume for a moment that $k$ indexes product characteristics or cost shifters that are exogenous to the demand and supply model. Let $J_f$ is a set of products produced by the firm $f$. Following Berry, Levinsohn and Pakes (1995), we employ as instruments:

1. the characteristic itself, $x_{i,k}$ and $w_{i,k}$;

2. the sum of the characteristics across products of the firm $f$ excluding characteristic of product $j$, $\sum_{r \neq i, r \in J_f} x_{r,k}$ and $\sum_{r \neq i, r \in J_f} w_{r,k}$;

3. the sum of the characteristics across the rival firm products, $\sum_{r \notin J_f} x_{r,k}$ and $\sum_{r \notin J_f} w_{r,k}$.

2.4 The Distribution of Fixed Cost

The last primitive of the model is the distribution of fixed costs, which helps to determine the observed number of products. We estimate the distribution of fixed costs from the entry behavior of firms. Because entry is discrete, the estimation problem is more difficult and we have to impose stronger assumptions. In particular, since unobservable part of fixed costs captures uncontrollable factors for firms such as price of energy and raw material, we assume that the firm allocates a part $\mu$ of unobservable fixed costs equally to its products, that is, a part $\mu$ of unobservable fixed costs are equal across its own products. Modelling product heterogeneity in fixed costs would require a major methodological advance that is beyond the scope of this article. For the empirical specification, we thus assume that fixed costs for product $j$, $j = 1, \ldots, J$ are

$$FC_j(\mu, \sigma, \boldsymbol{\tau}) = f e_j \cdot \boldsymbol{\tau} + \mu + \sigma \psi$$

(2.21)
where $f \mathbf{c}_j$ is $(1 \times N)$ vector of observed fixed cost shifter and $\mu+\sigma\psi$ represents unobservable (by econometrician) part of the fixed cost for product $j$ and $\psi$ is distributed standard normal, while $\tau$, $\mu$ and $\sigma$ are respectively $(N \times 1)$ vector of parameters and two scalar parameters to be estimated. We assume that there are $J$ existing products.

In a free entry equilibrium, firms introduce products until profits are driven to zero, with profit of product $j$ produced by firm $f$ is given by

$$
\pi^e_j(J_f) = Ms_j^e(J_f; \alpha, \beta, \lambda) \left(p_j^e(J_f; \alpha, \beta, \lambda, \gamma) - C_j(J_f; \alpha, \beta, \lambda, \gamma)\right) - FC_j(\mu, \sigma, \tau). \tag{2.22}
$$

This is rewriting of profit of product $j$ in (2.11) to emphasize the number $J_f$ of products firm $f$ produces under free entry. The $s_j^e(J_f; \alpha, \beta, \lambda)$ rewrites the market share in (2.3), $p_j^e(J_f; \alpha, \beta, \lambda, \gamma)$ the price in (2.17), $C_j(J_f; \alpha, \beta, \lambda, \gamma)$ the marginal cost, and $FC_j(\mu, \sigma, \tau)$ the fixed cost. Formally, given the integer constraint on $J_f$, the number $J_f$ of products firm $f$ produces satisfies the condition

$$
\pi^e_j(J_f) \geq 0, \quad \text{and} \quad \pi^e_j(J_f + 1) < 0. \tag{2.23}
$$

We further rewrite the model-calculated profit in (2.22) as

$$
\pi^e_j(J_f; \theta) = v_j^e(J_f; \theta) - \mu - \sigma \cdot \psi_j, \tag{2.24}
$$

where observed portion $v_j^e(J_f; \theta)$ of the model-calculated profit $\pi^e_j(J_f; \theta)$ is from (2.17)

$$
v_j^e(J_f; \theta) = Ms_j^e(J; \alpha, \beta, \lambda) \left(p_j^e(J; \alpha, \beta, \lambda, \gamma) - C_j(J; \alpha, \beta, \lambda, \gamma)\right) - f \mathbf{c}_j \cdot \tau
$$

$$
= Ms_j^e(J; \alpha, \beta, \lambda) \left\{ \frac{\lambda}{\lambda} \right\}
$$

$$
\left\{ \alpha \cdot \left\{ 1 + (\lambda - 1) s_j^e(\delta) - \lambda s_j^e(\delta) \right\} \right\} - f \mathbf{c}_j \cdot \tau. \tag{2.25}
$$
with $\boldsymbol{\theta} = (\alpha, \beta^T, \lambda, \gamma^T, \tau^T)^T$.

Order the products produced by firm $f$ from the most to least profitable. Then (2.23) is satisfied if and only if

$$\pi^e_{(1_f)}(J_f, \boldsymbol{\theta}) \geq \ldots \geq \pi^e_{(J_f)}(J_f; \boldsymbol{\theta}) \geq 0 > \pi^e_{(J_f+1)}(J_f; \boldsymbol{\theta}) \geq \ldots \geq \pi^e_{(J^+_f)}(J_f; \boldsymbol{\theta}),$$

(2.26)

where $J^+_f$ is the total number of products including those now retired by and those being developed by firm $f$ and $J_f$ denotes the number of products produced by firm $f$.

A number of products produced by firm $f$ equal to $J_f$ is observed in equilibrium if and only if the fixed costs are such that $J_f$ products make a profit but $J_f + 1$ products would not. The probability that $J_f$ or more products are introduced to the market is the probability that profit of the least profitable product is non-negative: $\pi_{(J_f)}(J) = v_{(J_f)}(J; \boldsymbol{\theta}) - \mu - \sigma \cdot \psi_{(J_f)} \geq 0$, which can be calculated from single one-dimensional integral over the density of $\psi_{(J_f)}$. Let $J^*_{f}$ be the random variable indicating the number of products introduced by firm $f$ to the market. The probability that $J_f$ products are introduced to the market is written as

$$\Pr\{J^*_f = J_f\} = \Pr\{J^*_f \geq J_f\} - \Pr\{J^*_f \geq J + 1\}$$

$$= \Pr \left\{ v^e_{(J_f)}(J_f; \boldsymbol{\theta}) - \mu - \sigma \cdot \psi_{(J_f)} \geq 0 \right\}$$

$$- \Pr \left\{ v^e_{(J_f+1)}(J_f; \boldsymbol{\theta}) - \mu - \sigma \cdot \psi_{(J_f+1)} \geq 0 \right\}$$

$$= \Pr \left\{ \psi_{(J_f)} \leq \frac{v^e_{(J_f)}(J_f; \boldsymbol{\theta}) - \mu}{\sigma} \right\}$$

$$- \Pr \left\{ \psi_{(J_f+1)} \leq \frac{v^e_{(J_f+1)}(J_f; \boldsymbol{\theta}) - \mu}{\sigma} \right\}$$

$$= \Phi \left( \frac{v^e_{(J_f)}(J_f; \boldsymbol{\theta}) - \mu}{\sigma} \right) - \Phi \left( \frac{v^e_{(J_f+1)}(J_f; \boldsymbol{\theta}) - \mu}{\sigma} \right),$$

(2.27)
where \( \Phi(\cdot) \) is the standard normal cumulative distribution function. If we assume that these probabilities (2.27) for firm \( f, f = 1, \ldots, F \) are independent, the log-likelihood function is written as

\[
\ell(\Theta) = \sum_{f=1}^{F} \log \left\{ \Phi \left( \frac{v_{(J_f)}(J_f; \theta) - \mu}{\sigma} \right) - \Phi \left( \frac{v_{(J_{f+1})}(J_{f+1}; \theta) - \mu}{\sigma} \right) \right\},
\]

(2.28)

where \( \Theta = (\theta^T, \mu, \sigma^T) \). We then have\(^1\)

\[
\frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} = \sum_{f=1}^{F} \begin{pmatrix}
\Phi \left( \frac{v_{(J_f)}(J_f; \theta) - \phi_{(J_{f+1})}(J_{f+1}; \theta)}{\sigma} \right) \Phi \left( \frac{v_{(J_{f+1})}(J_{f+1}; \theta) - \mu}{\sigma} \right) \\
- \Phi \left( \frac{v_{(J_{f+1})}(J_{f+1}; \theta) - \mu}{\sigma} \right) \\
- \Phi \left( \frac{v_{(J_{f+1})}(J_{f+1}; \theta) - \mu}{\sigma} \right) \\
\Phi \left( \frac{v_{(J_{f+1})}(J_{f+1}; \theta) - \mu}{\sigma} \right) + \Phi \left( \frac{v_{(J_{f+1})}(J_{f+1}; \theta) - \mu}{\sigma} \right) \\
- \Phi \left( \frac{v_{(J_{f+1})}(J_{f+1}; \theta) - \mu}{\sigma} \right) - \Phi \left( \frac{v_{(J_{f+1})}(J_{f+1}; \theta) - \mu}{\sigma} \right)
\end{pmatrix}^T.
\]

(2.29)

\section{3 Estimation}

\subsection{3.1 Generalized Method of Moment (GMM) Estimation}

In this chapter, we discuss GMM estimation algorithm with the moment condition of demand-and-supply side model and the first-order conditions on the maximum-likelihood estimation for entry model with respect to the parameters. The first-order conditions are properly thought of as moment

\( ^{1} \)In view of (2.17) and (2.25), it is clear that \( \mathbf{w}_\gamma \gamma \) is cancelled out and does not enter to the profit function in (2.25). Therefore we do not have to differentiate the likelihood (2.28) with respect to \( \gamma \).

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conditions\(^2\). The joint sample moment condition is written as \((1 \times (M_1 + M_2 + N + 2))\) vector:

\[
g_J(\Theta) = \begin{bmatrix} \frac{1}{J} \sum_{i=1}^{J} \xi_i(\alpha, \beta, \gamma) \cdot z_{i1} \\
\frac{1}{J} \sum_{i=1}^{J} \omega_i(\alpha, \beta, \lambda, \gamma) \cdot z_{i2} \end{bmatrix} \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} = \begin{bmatrix} \frac{1}{J}(\xi(\alpha, \beta, \lambda))^T \cdot Z_1 \\
\frac{1}{J}(\omega(\alpha, \gamma, \lambda))^T \cdot Z_2 \end{bmatrix} \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} = 0^{1 \times (M_1 + M_2 + N + 2)},
\]

(3.1)

where \(\xi\) denotes the \((J \times 1)\) vector of the unobserved demand characteristics \(\omega\) denotes the \((J \times 1)\) vector of the unobserved cost shifters, \(Z_1\) denotes the \((J \times M_1)\) matrix of demand-side instruments, \(Z_2\) denotes \((J \times M_2)\) matrix of supply-side instruments, \(\partial \ell(\Theta)/\partial (\mu, \sigma, \tau^T)\) denotes first order condition of log-likelihood function in (2.29), and \(0^{X \times Y}\) is \((X \times Y)\) zero matrix.

We employ Hansen’s (1982) GMM to estimate parameters \(\Theta\). The parameters are obtained by minimizing an objective function:

\[
Q(\Theta) = \{g_J(\Theta)\} \cdot \Omega^{-1}_J \cdot \{g_J(\Theta)\}^T,
\]

(3.2)

where \(\Omega^{-1}_J\) is the inverse of the random weighting matrix \(\Omega_J\) that converges almost surely to asymptotic covariance \(\Omega^0\) of the sample moment condition \(g_J(\Theta)\) with true value of parameters \(\Theta^0\). In other words,

\[
\Omega_J \xrightarrow{a.s.} \Omega^0 = \lim_{J \to \infty} J \cdot E \left[ \{g_J(\Theta)\}^T \cdot \{g_J(\Theta)\} \right].
\]

(3.3)

This weighting matrix \(\Omega^0\) minimizes asymptotic variance of parameters \(\Theta\). The asymptotic weighting matrix \(\Omega^0\) could be consistently estimated by

\[
\hat{\Omega}^0 = \begin{pmatrix}
\frac{1}{J} \sum_{i=1}^{J} \hat{\xi}_i(\xi_{i1})^T \cdot \{z_{i1}\} & \frac{1}{J} \sum_{i=1}^{J} \hat{\xi}_i(\xi_{i1})^T \cdot \{z_{i2}\} & \frac{1}{J} \sum_{i=1}^{J} \hat{\xi}_i(\xi_{i1})^T \cdot \{\frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)}\} \\
\frac{1}{J} \sum_{i=1}^{J} \hat{\omega}_i(\omega_{i1})^T \cdot \{z_{i1}\} & \frac{1}{J} \sum_{i=1}^{J} \hat{\omega}_i(\omega_{i1})^T \cdot \{z_{i2}\} & \frac{1}{J} \sum_{i=1}^{J} \hat{\omega}_i(\omega_{i1})^T \cdot \{\frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)}\} \\
\frac{1}{J} \sum_{i=1}^{J} \left\{ \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} \right\}^T \cdot \hat{\xi}_i(\xi_{i1}) & \frac{1}{J} \sum_{i=1}^{J} \left\{ \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} \right\}^T \cdot \hat{\omega}_i(\omega_{i1}) & \left\{ \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} \right\}^T \hat{\xi}_i(\xi_{i1}) \\
\frac{1}{J} \sum_{i=1}^{J} \left\{ \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} \right\}^T \cdot \hat{\omega}_i(\omega_{i1}) & \frac{1}{J} \sum_{i=1}^{J} \left\{ \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} \right\}^T \hat{\omega}_i(\omega_{i1}) & \left\{ \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} \right\}^T \left\{ \frac{\partial \ell(\Theta)}{\partial (\mu, \sigma, \tau^T)} \right\} \\
\end{pmatrix},
\]

(3.4)

\(^2\)The maximum likelihood estimator is zeroing the expected value of the derivatives of likelihood function with respect to the parameters, similarly to the GMM estimator.
where $\hat{\xi}_i = \xi_i(\hat{\alpha}, \hat{\beta}, \hat{\lambda})$ and $\hat{\omega}_i = \omega_i(\hat{\alpha}, \hat{\gamma}, \hat{\lambda})$.

### 3.2 Asymptotic Variance-covariance

We discuss the asymptotic variance-covariance matrix of the parameters. This matrix is written as

$$
\begin{bmatrix}
\frac{\partial g(\Theta)}{\partial \Theta} \cdot \Omega_j^{-1} \cdot \left\{ \frac{\partial g(\Theta)}{\partial \Theta} \right\}'
\end{bmatrix}.
$$

(3.5)

We describe the partial derivative of objective function $g(\Theta)$ with respect to parameters $\Theta$. That is,

$$
\frac{\partial g(\Theta)}{\partial \Theta} = \frac{\partial}{\partial \Theta} \left[ \frac{1}{J} \sum_{i=1}^{J} \xi_i(\alpha, \beta, \lambda) \cdot z_{i1} \right]
= \left[ \frac{1}{J} \sum_{i=1}^{J} \frac{\partial \xi_i(\alpha, \beta, \lambda)}{\partial \alpha} \cdot z_{i1} \left\{ \frac{1}{J} \sum_{i=1}^{J} \frac{\partial \omega_i(\alpha, \beta, \lambda, \gamma)}{\partial \alpha} \cdot z_{i2} \right\} \right]
= \left[ \frac{1}{J} \sum_{i=1}^{J} \frac{\partial \xi_i(\alpha, \beta, \lambda)}{\partial \beta} \cdot z_{i1} \left\{ \frac{1}{J} \sum_{i=1}^{J} \frac{\partial \omega_i(\alpha, \beta, \lambda, \gamma)}{\partial \beta} \cdot z_{i2} \right\} \right]
= \left[ \frac{1}{J} \sum_{i=1}^{J} \frac{\partial \xi_i(\alpha, \beta, \lambda)}{\partial \lambda} \cdot z_{i1} \left\{ \frac{1}{J} \sum_{i=1}^{J} \frac{\partial \omega_i(\alpha, \beta, \lambda, \gamma)}{\partial \lambda} \cdot z_{i2} \right\} \right]
$$

(3.6)

See appendix B for detail.
3.3 Estimation algorithm

We outline the algorithm. We index the number of iteration as $t$.

**step 0** prepares the necessary data along with an initial value of the parameters $\Theta^{t=0}$ and weighting matrix $\Omega^{t=0}$ in (3.4). See detail below;

**step 1** for the given value of parameters $\Theta^{t-1}$,

**step a** obtains unobserved demand characteristics $\hat{\xi}$ in (??);

**step b** estimates the market share $s_i^e(J; \alpha, \beta, \lambda)$ in (2.3) and within-the-nest market share $s_{i/B_i}^e(J; \alpha, \beta, \lambda)$ of product $i$, $i = 1, \ldots, J$;

**step c** estimates the price $p_i^e(J; \alpha, \beta, \lambda, \gamma)$ in (2.17) of product $i$ using $s_i^e(J; \alpha, \beta, \lambda)$ and $s_{i/B_i}^e(J; \alpha, \beta, \lambda)$ obtained in step a;

**step d** obtains unobserved cost shifters $\hat{\omega}$ in (2.19) using the price $p_i^e(J; \alpha, \beta, \lambda, \gamma)$ obtained in step c;

**step e** calculates the score function—the first order derivative—in (2.29) of log-likelihood using $s_i^e(J; \alpha, \beta, \lambda)$ obtained in step b and $p_i^e(J; \alpha, \beta, \lambda, \gamma)$ obtained in step c;

**step 2** for weighting matrix $\Omega^{t-1}$, searches for the value of parameters $\Theta^t$ which minimizes the objective function $Q(\Theta)$ in (3.2). See detail below;

**step 3** updates the weighting matrix $\Omega^t$ by the value of parameters obtained in step 2;

**step 4** returns to step 1 until parameters $\Theta$ converge. In the program, we evaluate the convergence if a metric $\{\Theta^t - \Theta^{t-1}\}^T \{\Theta^t - \Theta^{t-1}\} < 10^{-10}$.

**Detail of Step 0:** The required data are market size $M$, observed market share $s_i$, observed share $s_{i/B_i}$ in nest $B_i$ ($i \in B_t$), demand characteristics
\( \mathbf{x}_i \), observed price \( p_i \), and cost shifters \( \mathbf{w}_i \) for all product \( i \), fixed cost \( f_c \) for the least profitable products of all firms in 2006. In addition, those data of products withdrawn form the market by the each firm in 2005 are necessary. Berry and Waldfogel (1999) obtained the appropriate initial values of parameters by equation-by-equation estimation\(^3\). The initial values of parameters \( \beta \), \( \alpha \) and \( \lambda \) are obtained by instrumental variable method on demand equation (2.9). Those of parameters \( \gamma \) are obtained by instrumental variable method on price equation (2.17) given parameters \( \alpha \) and \( \lambda \). Those of parameters \( \tau \), \( \mu \) and \( \sigma \) are obtained by maximum likelihood estimation.

Set initial weighting matrix \( \Omega^{t=0} \) as the identity matrix.

**Detail of Step 2:** We minimize the GMM objective function \( Q(\Theta) \) with respect to parameters via multidimensional downhill simplex method (Nelder and Mead, 1965). In this operation, the GMM objective function \( Q(\Theta) \) is affected by the value of parameters via sample moment \( g_J(\Theta) \), since the weighting matrix \( \Omega^{t-1} \) is given.

## 4 Data

There are about 450 domestic and imported non-commercial models sold in Japanese market in 2006, the year the latest annual sales data are available. Japanese market has mini vehicle (kei car) segment, which accounts about 32% of the total sale volume. Mini vehicles belong to a category of small automobiles, which are designed to exploit automobile taxes and reg-

---
\(^3\) The parameters are estimated separately. The first step estimates demand parameters \( \alpha \), \( \beta \) and \( \lambda \) by applying instrumental method to demand equation (2.9). The second step estimates supply parameters \( \gamma \) by applying instrumental method to supply equation (2.17). The last step estimates parameters \( \mu \), \( \sigma \) and \( \tau \) for entry model by maximum likelihood estimation for the score function (2.29).
ulated with body size and engine: maximum length of 3.395 meters, width of 1.475 meters, height of 2.0 meters, engine displacement of 0.66 liters and horsepower of 64 ps. All firms designed their mini vehicles to fully take advantage of the regulation; as a result, the mini vehicles have almost identical length, width, and engine displacement. Due to this design of mini vehicles makes the mini vehicle segment unique and different from passenger vehicle segment. Therefore, we analyze the passenger vehicle and the mini vehicle segment separately. We only use 124 domestic models in the passenger vehicle segment and 36 models in the mini vehicle segment, those models cover about 91% of sales volume, a sizable portion in our estimation.

For each model in passenger vehicle segment, we use sales volume (in units of 10000), the number of months the automobile sold and vehicle characteristics including manufacturer suggested retail price (in 10 million yen units), max power⁴ (in 100 kilo watt times minute units), engine displacement (in litter), weight (in ton), size (measured by length times width times height in square meters), fuel efficiency (in 10 kilometer per litter units), automatic transmission dummy indicating if the transmission is automatic and body types—as in Berry, Levinsohn and Pakes (1995, 2004), Sudir (2001) and Petrin (2002). In this study, body types are sedan, station wagon, hatchback, coupe, minivan and SUV. We exclude reliability ratings because objective reliability statistics are not available to us.

For each model in mini vehicle segment, we use sales volume (in units of 10000), the number of months the automobile sold and vehicle characteristics including manufacturer suggested retail price (in 10 million yen units), max power (in 100 kilo watt times minute units), weight (in ton), fuel efficiency (in 10 kilometer per litter units), the year the firm made full model change

⁴1 kilo watt times minute in max power is approximately equal to 1.36 ps in horsepower
for the model, the number of the grade for the model, the number of the
door of the model, and the firm dummy indicating if the model produced by
the firm.

In order to treat bias of sales period, we remediante sales volume if each
model is sold for less than 12 months in 2006. For example, a model was in-
troduced in December and recorded 1,000 unit sales. Its annual sales volume
then became 1,000. However, it could have earned more annual sales volume
if it had introduced earlier. In order to avoid this bias, we remediante sales
volume as

\[
\frac{\text{the sales volume of the model}}{\text{the number of months the model sold}} \times 12.
\]  

(4.1)

The data of sales volume are from “Annual Report of New Car Regis-
tration (2007)” published by Japan Automobile Dealers Association and a
web-page (http://www.zenkeijikyo.or.jp/statistics/index.html) provided by
Japan Mini Vehicles Association. The data of price are from “Motor Maga-
zine” published by Motor magazine Inc. The data of other vehicle character-
istics come from “Annual Automobile Specifications (2007)”, published by
Society of Automotive Engineers of Japan.

Aside from these vehicle characteristics, we obtain additional data. Sim-
ilarly to Berry, Levinsohn and Pakes (1995), we gather data on the price of
gasoline and then one of our vehicle characteristics is cost of driving (in kilo-
meter per yen), calculated as the price of gasoline divided by fuel efficiency.
For each firm, we use the amount of investment to asset and R&D expenses
from Financial Statements in 2007 of each firm.
5 Result

The initial values of parameters for GMM estimation are given by the equation-by-equation estimation. The equation-by-equation estimation ignores interaction between demand, supply and entry models. Considering the interaction using GMM estimation, we can obtain more reliable results.

5.1 Passenger Vehicle Segment

The results of estimation in both equation-by-equation and GMM estimation are reported by Table 1 for demand and Table 2 for supply and entry. Columns 1 in the both tables report estimated parameters from equation-by-equation estimation, and columns 2 in the both tables report estimated parameters from GMM estimation. We discuss the imprecations as following.

Demand. We use price and following demand characteristics in the demand equation: engine displacement (Disp), weight class (WeightC), dummy variable indicating if side air bag is standard (SRS), dummy variable indicating if car navigation system is standard (Navi), cost of driving (CDrive), the number of year after full model change (FMChange), dummy variable indicating if body type is coupe (Coupe), dummy variable indicating if body type is minivan (Minivan), dummy variable indicating if price is over 5 million yen (Lux5), dummy variable indicating if product is produced by SUZUKI (SUZ), dummy variable indicating if product is produced by DAIHATSU (DAI). We also obtain correlation with in the body types—body types are used as nest.

According to Table 1, in GMM estimation, the parameters for Price, WeightC, CDrive, FMChange, Coupe, SUZ and DAI are negative and significantly different from zero; those for Disp, SRS, Navi, Minivan, Lux5 and the
Table 1: The result of estimation for demand

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Equation by equation</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef</td>
<td>SE</td>
</tr>
<tr>
<td>Price</td>
<td>-1.720</td>
<td>2.676</td>
</tr>
<tr>
<td>Disp</td>
<td>0.126</td>
<td>0.296</td>
</tr>
<tr>
<td>Weight</td>
<td>-0.143**</td>
<td>0.108</td>
</tr>
<tr>
<td>SRS</td>
<td>0.033</td>
<td>0.213</td>
</tr>
<tr>
<td>Navi</td>
<td>0.371</td>
<td>0.345</td>
</tr>
<tr>
<td>CDrive</td>
<td>-0.419</td>
<td>0.431</td>
</tr>
<tr>
<td>FMChange</td>
<td>-0.031</td>
<td>0.029</td>
</tr>
<tr>
<td>Coupe</td>
<td>-2.032***</td>
<td>0.249</td>
</tr>
<tr>
<td>Minivan</td>
<td>0.709***</td>
<td>0.137</td>
</tr>
<tr>
<td>Lux5</td>
<td>0.612</td>
<td>0.691</td>
</tr>
<tr>
<td>SUZ</td>
<td>-0.125</td>
<td>0.304</td>
</tr>
<tr>
<td>DAI</td>
<td>-0.211</td>
<td>0.377</td>
</tr>
<tr>
<td>Corr</td>
<td>0.890***</td>
<td>0.095</td>
</tr>
</tbody>
</table>

Significance Probability: *** p < 0.01, ** p < 0.05, * p < 0.1.

correlation within the nests is positive and significantly different from zero.

As expected, price has negative correlation on market share, indicating price sensitivity of consumers. Consumers prefer vehicles with bigger engine displacement, lower cost of driving, side air bags and car navi. Those results are consistent with previous studies. The correlation within the nests is 0.861 from GMM estimation, which imply that consumers tend to substitute automobiles within the nests.

22
Supply. We use following characteristics: intercept, natural logarithm of size (ln(size)), natural logarithm of the ratio of max power to weight (ln(MP/W)), dummy variable indicating if side air bags are standard, dummy variable indicating if side car navigation system is standard, dummy variable indicating if engine is hybrid (Hybrid) and natural logarithm of sales volume (ln(sales)).

According to Table 2, in GMM estimation, the parameters for ln(size), ln(MP/W), SRS, Navi, Hybrid are positive and significantly different from zero; those for Intercept and ln(sales) are negative and significantly different from zero.

As we expected, it cost more to produce bigger, more powerful, more fuel efficient vehicles with side air bags and car navigation system, and the economies of scale is working, since cost of production decreases as sales volume increases. Those results are consistent with the previous studies.

Entry. We use the R&D shared pro rata in accordance with price of each model within the firm (R&D(price)), which is calculated as

\[ R&D(price) = R&D \times \frac{p_i}{\sum_{j \in f} p_j}. \]  

(5.1)

According to Table 2, the mean \( \mu \) is negative and significantly different from zero. The standard deviation \( \sigma \) and R&D(price) are positive and significantly different from zero.

Estimated profit, market share and entry probability. Estimated profit, estimated market share and difference between observed market share and estimated market share are reported in Table 3.

Change of market share and profit. Tables 4 and 5 report change of market share and change of profit for each firm as the number of its products changes form -3 to +1.
Table 2: The result of estimation for supply and entry

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Equation by equation</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef</td>
<td>SE</td>
</tr>
<tr>
<td>Intercept</td>
<td>−0.945***</td>
<td>0.129</td>
</tr>
<tr>
<td>In(Size)</td>
<td>0.292***</td>
<td>0.038</td>
</tr>
<tr>
<td>In(MP/W)</td>
<td>0.212***</td>
<td>0.034</td>
</tr>
<tr>
<td>SRS</td>
<td>0.111***</td>
<td>0.024</td>
</tr>
<tr>
<td>Navi</td>
<td>0.186***</td>
<td>0.027</td>
</tr>
<tr>
<td>Hybrid</td>
<td>0.141***</td>
<td>0.029</td>
</tr>
<tr>
<td>In(sales)</td>
<td>−0.020**</td>
<td>0.010</td>
</tr>
<tr>
<td>μ</td>
<td>−0.364***</td>
<td>0.013</td>
</tr>
<tr>
<td>σ</td>
<td>0.675***</td>
<td>0.009</td>
</tr>
<tr>
<td>R&amp;D(price)</td>
<td>0.053***</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Significance Probability: *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 3: Estimated Profit and Entry Probability

<table>
<thead>
<tr>
<th></th>
<th>SUZUKI</th>
<th>DAIHATSU</th>
<th>TOYOTA</th>
<th>NISSAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit</td>
<td>133.54</td>
<td>37.13</td>
<td>1895.94</td>
<td>430.57</td>
</tr>
<tr>
<td>Market Share</td>
<td>3.273</td>
<td>0.962</td>
<td>31.742</td>
<td>9.561</td>
</tr>
<tr>
<td>(s^o − s^c)(%)</td>
<td>−1.405</td>
<td>−0.458</td>
<td>2.616</td>
<td>1.022</td>
</tr>
<tr>
<td></td>
<td>HONDA</td>
<td>MAZDA</td>
<td>MITSUBISHI</td>
<td>SUBARU</td>
</tr>
<tr>
<td>Profit</td>
<td>472.55</td>
<td>303.73</td>
<td>117.69</td>
<td>12.18</td>
</tr>
<tr>
<td>Market Share</td>
<td>9.961</td>
<td>6.522</td>
<td>2.949</td>
<td>0.338</td>
</tr>
<tr>
<td>(s^o − s^c)(%)</td>
<td>−2.463</td>
<td>−0.777</td>
<td>−0.911</td>
<td>1.588</td>
</tr>
</tbody>
</table>
Table 4: Change of Market Share

<table>
<thead>
<tr>
<th>Change of # of products</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUZUKI</td>
<td>3.180</td>
<td>3.255</td>
<td>3.266</td>
<td>3.273</td>
<td>3.925</td>
</tr>
<tr>
<td>DAIHATSU</td>
<td>0.588</td>
<td>0.911</td>
<td>0.953</td>
<td>0.962</td>
<td>0.998</td>
</tr>
<tr>
<td>TOYOTA</td>
<td>31.742</td>
<td>31.742</td>
<td>31.742</td>
<td>31.742</td>
<td>32.039</td>
</tr>
<tr>
<td>MITSUBISHI</td>
<td>2.939</td>
<td>2.949</td>
<td>2.949</td>
<td>2.949</td>
<td>3.017</td>
</tr>
<tr>
<td>SUBARU</td>
<td>0.000</td>
<td>0.152</td>
<td>0.298</td>
<td>0.338</td>
<td>1.558</td>
</tr>
</tbody>
</table>

Market shares for all firms increases as the number of the products increases. Profits for SUZUKI, DAIHATSU and SUBARU tend to increase as the number of the products increases. Profit for TOYOTA and NISSAN decrease as the number of own products increases.

Cross elasticities. Tables 6 and 7 report “cross elasticities of market share of the firm relative the number of products” and “cross elasticities of profit of the firm relative the number of products” respectively.

According to Tables 6, increase in the number of products for SUZUKI, DAIHATSU, NISSAN, HONDA, MAZDA, MITSUBISHI and SUBARU increases own market shares, while their rivals’ share decrease. According to Tables 7, increase in the number of products for SUZUKI, DAIHATSU and SUBARU increase own profits, while decrease rivals’ profit. On the other hand, Profit of TOYOTA, NISSAN, HONDA, MAZDA and MITSUBISHI decrease own profit and rivals’ profit.
Table 5: Change of Profit

<table>
<thead>
<tr>
<th>Change of # of producers</th>
<th>–3</th>
<th>–2</th>
<th>–1</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUZUKI</td>
<td>130.73</td>
<td>133.31</td>
<td>133.47</td>
<td>133.54</td>
<td>158.73</td>
</tr>
<tr>
<td>DAIHATSU</td>
<td>23.34</td>
<td>35.60</td>
<td>37.01</td>
<td>37.13</td>
<td>38.32</td>
</tr>
<tr>
<td>TOYOTA</td>
<td>1896.97</td>
<td>1896.65</td>
<td>1896.30</td>
<td>1895.94</td>
<td>1904.14</td>
</tr>
<tr>
<td>NISSAN</td>
<td>431.47</td>
<td>431.21</td>
<td>430.89</td>
<td>430.57</td>
<td>430.50</td>
</tr>
<tr>
<td>HONDA</td>
<td>472.79</td>
<td>472.86</td>
<td>472.83</td>
<td>472.55</td>
<td>472.15</td>
</tr>
<tr>
<td>MAZDA</td>
<td>302.93</td>
<td>303.95</td>
<td>303.77</td>
<td>303.73</td>
<td>303.53</td>
</tr>
<tr>
<td>MITSUBISHI</td>
<td>117.91</td>
<td>118.11</td>
<td>117.90</td>
<td>117.69</td>
<td>120.07</td>
</tr>
<tr>
<td>SUBARU</td>
<td>0.00</td>
<td>5.56</td>
<td>10.93</td>
<td>12.18</td>
<td>61.19</td>
</tr>
</tbody>
</table>

Table 6: Cross Elasticities of Market Share

<table>
<thead>
<tr>
<th>(%)</th>
<th>SUZ</th>
<th>DAI</th>
<th>TOY</th>
<th>NIS</th>
<th>HON</th>
<th>MAZ</th>
<th>MIT</th>
<th>SUB</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUZUKI</td>
<td>1.83</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>−0.27</td>
<td>0.00</td>
<td>−0.02</td>
</tr>
<tr>
<td>DAIHATSU</td>
<td>−0.16</td>
<td>3.73</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>−0.33</td>
<td>0.00</td>
<td>−0.02</td>
</tr>
<tr>
<td>TOYOTA</td>
<td>−0.10</td>
<td>−0.08</td>
<td>0.00</td>
<td>−0.05</td>
<td>−0.04</td>
<td>−0.11</td>
<td>0.00</td>
<td>−0.27</td>
</tr>
<tr>
<td>NISSAN</td>
<td>−0.08</td>
<td>−0.03</td>
<td>0.00</td>
<td>0.20</td>
<td>−0.01</td>
<td>−0.01</td>
<td>0.00</td>
<td>−0.09</td>
</tr>
<tr>
<td>HONDA</td>
<td>−0.09</td>
<td>−0.01</td>
<td>0.00</td>
<td>−0.01</td>
<td>0.26</td>
<td>−0.02</td>
<td>0.00</td>
<td>−0.05</td>
</tr>
<tr>
<td>MAZDA</td>
<td>−0.04</td>
<td>−0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>−0.15</td>
<td>0.82</td>
<td>0.00</td>
<td>−0.02</td>
</tr>
<tr>
<td>MITSUBISHI</td>
<td>−0.13</td>
<td>−0.12</td>
<td>0.00</td>
<td>−0.07</td>
<td>0.00</td>
<td>−0.02</td>
<td>0.02</td>
<td>−0.41</td>
</tr>
<tr>
<td>SUBARU</td>
<td>−0.01</td>
<td>−0.15</td>
<td>0.00</td>
<td>−0.08</td>
<td>0.00</td>
<td>−0.24</td>
<td>0.00</td>
<td>35.09</td>
</tr>
<tr>
<td>Own</td>
<td>1.83</td>
<td>3.73</td>
<td>0.00</td>
<td>0.20</td>
<td>0.26</td>
<td>0.82</td>
<td>0.02</td>
<td>35.09</td>
</tr>
<tr>
<td>Rival</td>
<td>−0.60</td>
<td>−0.40</td>
<td>0.00</td>
<td>−0.21</td>
<td>−0.22</td>
<td>−1.00</td>
<td>0.00</td>
<td>−0.88</td>
</tr>
</tbody>
</table>
Table 7: Cross Elasticity of Profit

<table>
<thead>
<tr>
<th>(%)</th>
<th>SUZ</th>
<th>DAI</th>
<th>TOY</th>
<th>NIS</th>
<th>HON</th>
<th>MAZ</th>
<th>MIT</th>
<th>SUB</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUZKI</td>
<td>0.41</td>
<td>−0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>−0.34</td>
<td>0.00</td>
<td>−0.02</td>
</tr>
<tr>
<td>DAIHATSU</td>
<td>−0.16</td>
<td>1.29</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>−0.36</td>
<td>0.00</td>
<td>−0.02</td>
</tr>
<tr>
<td>TOYOTA</td>
<td>−0.09</td>
<td>−0.23</td>
<td>−0.98</td>
<td>−0.13</td>
<td>−0.04</td>
<td>−0.35</td>
<td>0.00</td>
<td>−0.77</td>
</tr>
<tr>
<td>NISSAN</td>
<td>−0.07</td>
<td>−0.03</td>
<td>0.00</td>
<td>−1.50</td>
<td>−0.01</td>
<td>−0.01</td>
<td>0.00</td>
<td>−0.08</td>
</tr>
<tr>
<td>HONDA</td>
<td>−0.08</td>
<td>−0.01</td>
<td>0.00</td>
<td>−0.01</td>
<td>−1.06</td>
<td>−0.02</td>
<td>0.00</td>
<td>−0.04</td>
</tr>
<tr>
<td>MAZDA</td>
<td>−0.03</td>
<td>−0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>−0.28</td>
<td>−0.14</td>
<td>0.00</td>
<td>−0.02</td>
</tr>
<tr>
<td>MITSUBISHI</td>
<td>−0.14</td>
<td>−0.14</td>
<td>0.00</td>
<td>−0.08</td>
<td>0.00</td>
<td>−0.02</td>
<td>−1.45</td>
<td>−0.48</td>
</tr>
<tr>
<td>SUBARU</td>
<td>−0.01</td>
<td>−0.16</td>
<td>0.00</td>
<td>−0.09</td>
<td>0.00</td>
<td>−0.26</td>
<td>0.00</td>
<td>30.63</td>
</tr>
<tr>
<td>Own</td>
<td>0.41</td>
<td>1.29</td>
<td>−0.98</td>
<td>−1.50</td>
<td>−1.06</td>
<td>−0.14</td>
<td>−1.45</td>
<td>30.63</td>
</tr>
<tr>
<td>Rival</td>
<td>−0.57</td>
<td>−0.58</td>
<td>0.00</td>
<td>−0.32</td>
<td>−0.35</td>
<td>−1.37</td>
<td>−0.01</td>
<td>−1.44</td>
</tr>
</tbody>
</table>
Conclusion. In terms of market share, adding one more product increase own market share (except HONDA) so that firms should introduce more products. SUZUKI, MAZDA, MITSUBISHI and SUBARU should increase the number of products in terms of profit. However, entry probability of SUZUKI, MAZDA, and MITSUBISHI are zero, so that only SUBARU can increase the number of products.

5.2 Mini Vehicle Segment

The results of estimation in both equation-by-equation and GMM estimation are reported by Table 8 for demand and Table 9 for supply and entry. Columns 1 in the both tables report estimated parameters from equation-by-equation estimation, and columns 2 in the both tables report estimated parameters from GMM estimation. We discuss the imprecations as following.

Demand. We use price and following demand characteristics in the demand equation: fuel efficiency (FE), the ratio of max power to weight (MP/W), the number of year past after the firm made full model change for the model (FMChage), the number of the grades for a model (#Grade), firm dummy for SUZUKI and DAIHATSU. We also obtain correlation with in the firms—firms are used as nest.

According to Table 8, in GMM estimation, the parameters for price, FE and FMC are negative and significantly different from zero; those for MP/W, #Grade, SUZUKI, DAIHATSU and the correlation within the nests is positive and significantly different from zero.

As expected, price has negative correlation on market share, indicating price sensitivity of consumers. Consumers prefer powerful and newer vehicles with variase grade. The correlation within the nests is 0.752 from GMM es-
Table 8: The result of estimation for demand (Mini Vehicle)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Equation by equation</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef</td>
<td>SE</td>
</tr>
<tr>
<td>Price</td>
<td>-7.521</td>
<td>6.849</td>
</tr>
<tr>
<td>FE</td>
<td>-0.955*</td>
<td>0.733</td>
</tr>
<tr>
<td>MP/W</td>
<td>0.315</td>
<td>0.362</td>
</tr>
<tr>
<td>FMC</td>
<td>-0.073**</td>
<td>0.044</td>
</tr>
<tr>
<td>#Grade</td>
<td>0.006</td>
<td>0.031</td>
</tr>
<tr>
<td>suzuki</td>
<td>0.710***</td>
<td>0.266</td>
</tr>
<tr>
<td>daihatsu</td>
<td>0.189</td>
<td>0.386</td>
</tr>
<tr>
<td>cor</td>
<td>0.857***</td>
<td>0.197</td>
</tr>
</tbody>
</table>

Significance Probability: *** p < 0.01, ** p < 0.05, * p < 0.1.

estimation, which imply that consumers tend to substitute automobiles within the nests. We do not expect that products with higher level of fuel efficiency are not popular. The reason is that mini vehicles already have high fuel efficiency so that consumers value the other product characteristics.

Supply. We use following characteristics: Intercept, the ratio of max power to weight (MP/W), weight (W), the number of doors (#Door) and natural logarithm of sales volume (log(Sales)).

According to Table 9, in GMM estimation, the parameters for MP/W, W and #door are positive and significantly different from zero; those for intercept and log(sales) are negative and significantly different from zero.

As we expected, it cost more to produce more powerful, heavier vehicles with more doors. The economies of scale is working, since cost of production
Table 9: The result of estimation for supply and entry (Mini Vehicle)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Equation by equation</th>
<th>GMM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef</td>
<td>SE</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.446*** 0.097 0.000</td>
<td>-0.398*** 0.085 0.000</td>
</tr>
<tr>
<td>MP/W</td>
<td>0.031*** 0.008 0.000</td>
<td>0.055*** 0.004 0.000</td>
</tr>
<tr>
<td>W</td>
<td>0.041*** 0.007 0.000</td>
<td>0.013** 0.007 0.025</td>
</tr>
<tr>
<td>#Door</td>
<td>0.012** 0.006 0.030</td>
<td>0.082*** 0.011 0.000</td>
</tr>
<tr>
<td>ln(Sales)</td>
<td>-0.001 0.003 0.295</td>
<td>-0.023*** 0.003 0.000</td>
</tr>
<tr>
<td>(\mu)</td>
<td>-0.868*** 0.189 0.000</td>
<td>-0.374 0.771 0.314</td>
</tr>
<tr>
<td>(\sigma)</td>
<td>2.391*** 0.205 0.000</td>
<td>2.122*** 0.629 0.000</td>
</tr>
<tr>
<td>R&amp;D(price)</td>
<td>0.424*** 0.040 0.000</td>
<td>0.214 0.332 0.261</td>
</tr>
<tr>
<td>Inv(price)</td>
<td>-0.532*** 0.029 0.000</td>
<td>0.488*** 0.100 0.000</td>
</tr>
</tbody>
</table>

Significance Probability: *** \( p < 0.01 \), ** \( p < 0.05 \), * \( p < 0.1 \).

decreases as sales volume increases.

**Entry.** We use R&D (R&D(price)) and capital investment (Invest(price)) shared pro rata in accordance with price of each model within the firm.

According to Table 9, the mean \( \mu \) is negative and significantly different from zero. The standard deviation \( \sigma \), R&D(price) and Invest(price) are positive and significantly different from zero. AD(price) is negative and significantly different from zero.

**Estimated profit, market share and entry probability.** Estimated profit, market share and difference between observed market share and estimated market share for each firm are reported in Table 10.
Table 10: Estimated Profit and Entry Probability

<table>
<thead>
<tr>
<th></th>
<th>DAIHATSU</th>
<th>HONDA</th>
<th>SUZUKI</th>
<th>MITSUBISHI</th>
<th>SUBARU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit</td>
<td>505.030</td>
<td>165.456</td>
<td>626.736</td>
<td>181.914</td>
<td>185.226</td>
</tr>
<tr>
<td>(s^\circ - s^e) (%)</td>
<td>2.021</td>
<td>-2.517</td>
<td>-0.001</td>
<td>2.368</td>
<td>3.077</td>
</tr>
</tbody>
</table>

Table 11: Change of Market Share

<table>
<thead>
<tr>
<th>Change of # of productsShare</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAIHATSU</td>
<td>20.60</td>
<td>20.73</td>
<td>20.87</td>
<td>20.94</td>
<td>21.04</td>
</tr>
<tr>
<td>HONDA</td>
<td>5.89</td>
<td>6.51</td>
<td>6.91</td>
<td>7.17</td>
<td>7.32</td>
</tr>
<tr>
<td>SUZUKI</td>
<td>27.24</td>
<td>27.24</td>
<td>27.25</td>
<td>27.25</td>
<td>27.23</td>
</tr>
<tr>
<td>MITSUBISHI</td>
<td>6.81</td>
<td>7.11</td>
<td>7.28</td>
<td>7.37</td>
<td>7.34</td>
</tr>
<tr>
<td>SUBARU</td>
<td>5.79</td>
<td>6.34</td>
<td>6.64</td>
<td>6.79</td>
<td>6.70</td>
</tr>
</tbody>
</table>

**Change of market share and profit.** Tables 11 and 12 report change of market share and change of profit for each firm as the number of its products changes form -3 to +1.

Market shares for DAIHATSU and HONDA increase as the number of the products increases. Profits for all firm decrease as increase in the number of own products.

**Cross elasticities.** Tables 13 and 14 report “cross elasticities of market share of the firm relative the number of products” and “cross elasticities of profit of the firm relative the number of products” respectively.

According to Tables 13, increase in the number of products for all firms increase own market shares but decrease rival’s market share. According to
Table 12: Change of Profit

<table>
<thead>
<tr>
<th>Change of # of producers</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-3</td>
</tr>
<tr>
<td>DAIHATSU</td>
<td>531.93</td>
</tr>
<tr>
<td>HONDA</td>
<td>522.33</td>
</tr>
<tr>
<td>SUZUKI</td>
<td>635.94</td>
</tr>
<tr>
<td>MITSUBISHI</td>
<td>227.57</td>
</tr>
<tr>
<td>SUBARU</td>
<td>519.80</td>
</tr>
</tbody>
</table>

Table 13: Cross Elasticities of Market Share

<table>
<thead>
<tr>
<th>(%)</th>
<th>DAI</th>
<th>HON</th>
<th>SUZ</th>
<th>MIT</th>
<th>SUB</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAIHATSU</td>
<td>2.93</td>
<td>-1.12</td>
<td>-0.02</td>
<td>-0.49</td>
<td>-0.64</td>
</tr>
<tr>
<td>HONDA</td>
<td>-0.78</td>
<td>14.45</td>
<td>-0.02</td>
<td>-0.49</td>
<td>-0.64</td>
</tr>
<tr>
<td>SUZUKI</td>
<td>-0.78</td>
<td>-1.12</td>
<td>0.05</td>
<td>-0.49</td>
<td>-0.64</td>
</tr>
<tr>
<td>MITSUBISHI</td>
<td>-0.78</td>
<td>-1.12</td>
<td>-0.02</td>
<td>6.16</td>
<td>-0.64</td>
</tr>
<tr>
<td>SUBARU</td>
<td>-0.78</td>
<td>-1.12</td>
<td>-0.02</td>
<td>-0.49</td>
<td>8.74</td>
</tr>
<tr>
<td>Own</td>
<td>2.93</td>
<td>14.45</td>
<td>0.05</td>
<td>6.16</td>
<td>8.74</td>
</tr>
<tr>
<td>Rival</td>
<td>-3.10</td>
<td>-4.47</td>
<td>-0.08</td>
<td>-1.96</td>
<td>-2.54</td>
</tr>
</tbody>
</table>

Tables 14, increase in the number of products for all firms decrease own and rivals’ profits. Increase the number of products decrease rivals’ profit except SUZUKI’s.

Conclusion. In terms of market share, adding one more product increase own market share for DAIHATSU and HONDA so that they should introduce more products to obtain market share. Entry probability of HONDA, SUZUKI, MITSUBISHI, SUBARU are less than 1%, so that only DAI-
HATSU can increase the number of products.

6 Discussion

In this study, we tried to reduce computational burden by using the simple models. The models have weaknesses so that they may be less-accurate than some models. We discuss some models which allows for more realistic situation.

**Demand model**  We treat the consumer specific taste $\epsilon_{ni}$ as random error term. The random coefficient model in Berry, Levinsohn and Pakes (1995), on the other hand, captures the consumer specific taste.

They build on a Cobb-Douglas utility function, generating the term $\log(y_n - p_i)$ where $y_i$ denotes disposable income of consumer $n$. The mean utility level $\delta_i$ specified by the linear function (??) is not reasonable for some products such as automobile. They also take into account preference of consumer $n$ distributed specific distribution. It involves the problem of computational
burden in the integral, even if we know the exact distribution of the preference of consumer $n$.

**Supply model** We assumed that each firm decides the price of its product to maximize the profit from the product as in Berry (1994). Berry, Levinsohn and Pakes (1995), on the other hand, employ more natural assumption that the firm decides the prices of its products to maximize the profit from its product set. In this case, specification of price equation involves interaction between products of a firm—price of a product is influenced by other products of the firm.

**Entry model** The ordered probit model reduces the difficulty of calculation because the entry probability is obtained by subtraction of two single integrals. However, it is more natural that the unobserved part of profit ($\mu + \sigma \cdot \psi_i$) is different for each product. The model in Berry (1992) solves this problem. The entry probability is obtained by examining whether profit of each product is non-negative. This model achieves much of the richness of real-world automobile market.
Bibliography


